IS 5285 (1998): Fibre Analysis of Paper and Board - Methods of Test [CHD 15: Paper and its products]

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भारतीय मानक

कागज एवं बोर्ड के रेशे विश्लेषण — परीक्षण पद्धतियाँ

(पहला पुनरीक्षण)

Indian Standard

FIBRE ANALYSIS OF PAPER AND BOARD — METHODS OF TEST

(*First Revision*)

ICS 85.060

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

May 1998

Price Group 11

AMENDMENT NO. 1 MARCH 2002
TO
IS 5285 : 1998 FIBRE ANALYSIS OF PAPER AND BOARD — METHODS OF TEST

(*First Revision*)

(*Page* 7, *Table* 1) — Insert the following at the end:

(1)	(2)	(3)
xx)	Softwood Thermo mechanical Pulp (TMP)	1.73
xxi)	Softwood Refiner mechanical Pulp (RMP)	1.59
xxii)	Softwood Semi-chemical Pulp (SCP)	1.14
xxiii)	Eucalyptus Chemi-mechanical pulp (CMP)	0.75

(CHD 15)

Reprography Unit, BIS, New Delhi, India

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Paper and Its Products (Excluding Packaging Materials) Sectional Committee had been approved by the Chemical Division Council.

This standard was first published in 1969. The need for revision of this standard had been felt for a long time, firstly, because of the technological advances since 1969 and secondly it had to be made more comprehensive to accommodate changing fibrous raw material sources used by the Indian Paper Industry.

The methods described in this standard are essentially similar to those prescribed by the Technical Association of Pulp and Paper Industry, U.S.A. and American Society for Testing and Materials. Methods for other fibrous sources such as Eucalyptus, Wheat, Straw, Rice straw, Grasses which are now being used increasingly in our paper industry, have been added to this standard on the basis of detailed investigations carried out at Central Pulp and Paper Research Institute, Saharanpur.

For exact identification of fibres and accurate results considerable training and experience are necessary. The analyst should make frequent use of standard samples of known composition or of authentic fibre samples and should become thoroughly familiar with the appearance of different fibres and their behaviour when treated with various stain.

Colour reactions of various pulps using Herzberg stain and 'C' stain have been investigated. It is impossible to differentiate between various pulp types as almost all of them have given similar reactions. It would have been better if other stains like Selleger's stain, Wilson's stain, Alexander's stain and Du Pont stains were also investigated, for our fibrous sources/raw material pulps. The colour reactions on pulp using other stains will be included in the standard after examining sufficient data as and when available. Information on this subject is given in Annex A.

A knowledge of morphological characteristics of different fibres is helpful and in some cases essential for their identification. Only staining of fibres does not help in identifying the fibres like Bamboo (*Bambusa arundinacea and Melocanna bambusoides),* Eucalyptus *(Eucalypt* sp., *E. tereticornis)* and Bagonne *Saccharum officinarum* if the above three or two are present together. Similarly, if the following fibrous material or few of them together are forming the composition of Paper/Board, staining of fibres alone will not enable the characterization of fibres:

a) Wheat straw *(Trilicum vulgare)*
b) Rice straw *(Oryzeanativa)*
c) Sabai grass *(Eulaliopsis binata)*
d) KHAR grass *(Saccharum munja)*
e) KAHI grass *(Saccharum spontaneum)*

For this purpose, study of morphological characteristics is necessary which not only identifies special fibres but also helps in applying the correct mass factor. Some information on this subject is given in Annex B.

In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2:1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

FIBRE ANALYSIS OF PAPER AND BOARD — METHODS OF TEST

(*First Revision*)

1 SCOPE

This standard prescribes methods for identification of fibres of important indigenous and imported pulps mainly used and present in the sample of paper, board and their quantitative estimation.

2 REFERENCES

The Indian Standards listed below contain provisions which through reference in this text, constitute provisions of this Indian Standard. At the time of publication, the editions indicated were valid. All standards are subject to revisions, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the Indian Standards indicated below:

IS No.	*Title*
1070 : 1992	Reagent grade water *(third revision)*
1103 : 1984	Brushes, artist's *(third revision)*
3099	Microscopes — Slips and slides:
(Part 1) : 1992	Microscope slips *(first revision)*
(Part 2) : 1992	Microscope slides *(first revision)*

3 TEST SPECIMEN

Single composite test specimen of approximately 0.2 to 0.5 g shall be selected in a manner that it represents all the test units of the sample to be analysed.

4 APPARATUS

4.1 Microscope

Any suitable microscope may be used. Following type is, however, recommended:

A binocular type compound microscope equipped with a graduated mechanical stage, Abbe condenser, triple nosepiece and an optical equipment consisting of two eyepieces of ×8 or ×10 magnification and three objectives of 48 mm, 16 mm and 4 mm focal length is recommended. A magnification of 80 to 100 diameters is recommended for observation of fibre colours. Although a higher magnification may be desirable for studying morphological characteristics, at the same time lower magnification of 20 to 40 diameter is found to be more convenient for measuring fibre length. One of the eyepieces shall be provided with cross-hair or pointer dot for counting the fibres passing under it and the other eyepiece shall have a micrometer scale with 100 equal divisions for measurement.

NOTE — A PIRA fibre length counter in conjunction with Projection Microscope may be used. The use of this counter helps in measurement of fibre dimension in lesser time, that too with ease. Any suitable projection microscope may be used for ease of measurements.

4.2 Slides and Cover Slips

Standard microscope glass slides, 25 mm × 75 mm, and No. 2 cover slips, 25 mm × 25 mm [*see* IS 3099 (Parts 1 and 2)

NOTE — It is desirable to store the slides and cover slips in a solution of ethyl alcohol and water (1:1 *v/v*).

4.3 Dropper

A glass tube of about 10 cm length and 8 mm internal diameter with one end fitted with a rubber bulb and the other carefully smoothened but not tapering. The tube shall be graduated to deliver 0.5 ml.

4.4 Hot Plate

A plate with a plane level top of solid metal, having black matt finish, provided with a control to maintain the temperature of the surface between 50 and 60°C.

4.5 Dissecting Needles

Two straight, pointed mounted needles, preferably of stainless steel or some other corrosion resistant alloys (for example, Platinum, Iridium, etc).

4.6 Glass Marking Equipment

Glass marking pencil, diamond tipped metallic pencil or an aluminium stearate solution for marking lines on the slide.

4.7 Light Source

A 15 Watt day light fluorescent tube, 60 watt frosted electric lamp or equivalent day light source.

4.8 Artist's Brush

No. 1 Sable-hair or squirrel hair brush (*see* IS 1103).

5 REAGENTS

5.0 Unless otherwise specified pure chemicals and fresh distilled water (*see* IS 1070) shall be employed in tests.

NOTE — 'Pure chemicals' shall mean chemicals that do not contain impurities which affect the results of analysis.

5.1 Glass Marking Solution

Aluminium stearate solution for marking lines on the slide prepared as follows:

5.1.1 To 500 ml of water add 15 g of shavings of a good grade of soap and stir until the soap is completely dissolved. To this solution add 10 g of pure Aluminium Sulphate [$Al_2 (SO_4)_3.18H_2O$], dissolved in minimum quantity of distilled water. A white precipitate is formed. Stir the solution till the precipitate coagulates into a wax like mass. It is lifted and placed in a desiccator for 48 h. Store in a well stoppered bottle to be used as needed.

5.1.2 To 50 ml of benzene in a glass stoppered bottle add 0.7 g of the desiccated aluminium stearate (*see* **5.1.1**). Shake well each day until completely dissolved. This usually requires about 10 days. The solution is then ready for use.

NOTE — If after several weeks it is found that the solution has lost some of its capacity as a water repellant add a small pellet of aluminium stearate to the solution. This will correct the condition within few hours.

5.2 Herzberg Stain

5.2.1 *Solution A — Zinc Chloride Solution*

About 25 ml of water is added to 50 g of dry zinc chloride to make a solution of 1.80 specific gravity at 27°C (fused sticks of $ZnCl_2$ in sealed bottles or crystals should be used).

5.2.2 *Solution B — Iodide — Iodine Solution*

Dissolve 0.25 g of iodine and 5.25 g of potassium iodide in 12.5 ml of water.

5.2.3 Mix entire Solution B with 25 ml of Solution A. Pour the mixed solution into a tall cylinder and allow it to stand until clear (12-24 h). Decant the supernatant liquid into an amber-coloured glass stoppered bottle and add a leaf of iodine to the solution. Protect the stain as much as possible from exposure to light and air.

NOTE — For special tests, the Herzberg stain may be modified by adding more zinc chloride to accentuate the blue or more iodine to accentuate the red. However, modification is not recommended for normal use.

5.3 Graff 'C' Stain

It is light sensitive stain and lasts only for 2 months. It is to be kept in dark coloured glass stoppered bottles, preferably wrapped with black paper. It is prepared from following four solutions, namely, A, B, C and D in the proportion of 20 ml : 10 ml : 10 ml : 12.5 ml.

5.3.1 *Solution A*

Dissolve 40 g of aluminium chloride ($AlCl_3.6H_2O$) in 100 ml of water to make a solution of 1.15 relative density at 27°C.

5.3.2 *Solution B*

Dissolve about 100 g of calcium chloride ($CaCl_2$) in 150 ml of water to make a solution of 1.36 relative density at 27°C.

5.3.3 *Solution C*

Add 25 ml of distilled water to 50 g of dry zinc chloride ($ZnCl_2$) to make a solution of 1.80 relative density at 27°C (Fused reagent grade sticks in sealed bottles or crystals should be used. Zinc chloride from a previously opened bottle should not be used).

5.3.4 *Solution D*

0.65 g of dry iodine and 0.90 g of dry potassium iodide are dissolved in 50 ml of water. The reagents shall be mixed and crushed together with a little water and then adding the required water slowly with stirring until the solution is complete.

NOTE — Solutions are made with reagent grade chemicals and distilled water. The solution should be of the exact relative density specified and measured accurately with graduated pipettes.

5.3.5 The mixture of all the four solutions, namely, A, B, C and D in the proportion mentioned above (*see* **5.3.1** to **5.3.4)** is poured into tall, narrow vessel and placed in dark. After 12-24 h when the precipitate has settled, draw off with a pipette the clear portion of the solution into a dark bottle and add a leaf of iodine. Keep in the dark when not in use.

5.4 Lofton Merrit Stain

5.4.1 *Solution A*

Dissolve 2 g of malachite green in 100 ml of water.

5.4.2 *Solution B*

Dissolve 1 g of basic fuchsin in 100 ml of water.

5.4.3 Mix 30 ml of solution A with entire Solution B and store in an amber coloured bottle.

5.5 Spot Stains for Groundwood

5.5.1 *Phloroglucinol*

Dissolve 1 g of phloroglucinol in a mixture of 50 ml methyl alcohol, 50 ml of concentrated hydrochloric acid and 50 ml of water. This formula gives a water clear solution that turns yellowish slowly with age. If a stronger stain is desired, the water may be omitted. The life of the solution will be prolonged if it is protected from light.

5.5.2 *Aniline Sulphate*

Dissolve 1 g of aniline sulphate in 50 ml of water and add a drop of concentrated sulphuric acid.

6 DISINTEGRATION OF SAMPLES AND PREPARATION OF STANDARD SUSPENSION

6.1 Ordinary Papers

Tear the sample into small pieces, weigh 0.5 g and place in a small beaker (200 ml or 250 ml capacity). Cover the sample with water and boil it on a hot plate. Decant the water and roll the pieces into small pellets between the fingers. Place the pellets in a large test-tube with a little water and shake vigorously, with addition of small quantities of water from time to time, until the paper is thoroughly defibred. Glass beads may be added to the test-tube to aid in the disintegration. The suspension is diluted to a consistency of about 0.05 percent.

6.2 Resistant Papers

Carry out the process as in **6.1**. If the paper is not defibred, place it in a small beaker (200 ml or 250 ml capacity), add 1 percent sodium hydroxide solution and heat gently on a hot plate at 60°C or near boiling temperatures. Allow it to cool, taking special care that fibres do not stick to wall of the beaker. Remove the alkali solution and wash the paper two or three times with water by decantation. Cover the sample with 0.05 N hydrochloric acid for about 20 to 30 min and wash again several times with water by decantation. The paper is rolled into pellets and defibred as mentioned under **6.1.**

NOTE — Paper containing wool fibres, however, should not be treated with sodium hydroxide in the manner indicated above, as the alkali will dissolve wool.

6.3 Specially Treated Papers

6.3.1 If the specimen is not disintegrated by procedure given in **6.1** and **6.2**, use one of the following special methods.

6.3.1.1 Standardized methods cannot be specified for the disintegration of papers containing tar, asphalt, rubber, viscose, etc, or parchment papers, because the procedure needs to be varied according to the material, the amount present and the nature of the treatment. The following methods are given as a guide.

6.3.2 *Paper Containing Tar, Asphalt and Viscose*

6.3.2.1 *Method 1*

Place the sample in a dish, cover with kerosene and digest on a steam bath for 1 h. After this, remove the specimen and press it between blotters, treat it again on the steam bath and again press between blotters, then extract with cold benzene until the solution is clear. No sodium hydroxide should be used in the final disintegration of these papers because of the possible presence of wool fibres.

6.3.2.2 *Method 2*

Take several convenient containers (250-ml beakers) nearly half filled with carbon tetrachloride. Cut the test specimen into convenient squares and immerse in the first container. After several minutes in the first container, transfer the squares to the next container using forceps. Do not allow the squares to dry. In the case of laminated papers, the sheets may be separated easily after the first or second soaking and this should be done removing any screen or mesh, which can be treated separately, if desired. Continue moving the specimen into fresh carbon tetrachloride until the liquid remains clear after the specimen has been agitated in it for several minutes, then remove the specimen and allow to air dry. After drying disintegrate the specimen in the usual manner.

6.3.2.3 *Method 3*

Place the specimen in a soxhlet or similar extractor and extract with chloroform, carbon tetrachloride, dioxane, trichloroethylene or similar solvents. Air dry the specimen and disintegrate in the usual manner.

6.3.3 *Rubber Treated Papers*

Extract the paper for 6 h in a soxhlet extractor with isopropyl benzene (cumene), dry and then boil in water to which a little wetting agent has been added. Defibre the paper in water in the usual manner.

NOTE — In rare cases, treatment with 1 percent sodium hydroxide solution may be necessary.

6.3.4 *Parchment Papers*

6.3.4.1 *Method 1*

To 250 ml of water add 25 ml of concentrated sulphuric acid and cool to 50 to 60°C. Place the paper in the acid and when the paper begins to disintegrate, stir quickly and pour into a 1 000 ml beaker, two-thirds filled with water.

6.3.4.2 *Method 2*

Soak the sample for about 5 min in concentrated hydrochloric acid, wash and boil in 0.5 percent sodium hydroxide solution. Repeat this sequence, if necessary. Then wash, acidify with dilute hydrochloric acid, again wash. Boil in a little water with a suitable wetting agent and disintegrate.

6.3.5 *Pyroxylin-Treated Papers*

Extract or remove the pyroxylin with cellosolve (Ethylene glycol monoethyl ether), ethyl acetate or amyl acetate.

6.3.6 *Wet Strength Papers*

6.3.6.1 *Method 1*

Tear the paper into small pieces and place in a beaker, cover with 5 percent aluminium sulphate solution and boil for 5 to 20 min, depending upon the amount of wet strength percent. Decant the alum solution, wash and proceed as in **6.2** for resistant papers.

6.3.6.2 *Method 2*

When an estimation of degree of beating of the fibres is not required, the sample may be disintegrated in water in a high speed mixer.

NOTE — Alkaline cured resins may be repulped with sodium hydroxide at 38°C and *p*H 10.

6.3.7 *Highly Coloured Papers*

If the paper is highly coloured, remove the dyes by one of the following methods and then disintegrate by the usual procedure. The treatment selected will depend upon the characteristics of the dyes.

6.3.7.1 *Method 1*

The paper is extracted with ethyl alcohol, ammonium hydroxide, acetic acid or hydrochloric acid.

6.3.7.2 *Method 2*

The dye is oxidized by treatment with nitric acid or hypochlorite bleach liquor.

6.3.7.3 *Method 3*

The dye is reduced with sodium hydrosulphite, zinc hydrosulphite, stannous chloride or hydrochloric acid and zinc.

7 PREPARATION OF SLIDES

Rule off 25 mm from each end of a clean slide with a glass marking pencil, diamond tipped metallic pencil or with the help of a brush dipped in aluminium stearate solution (a 1.5 percent solution of aluminium stearate in benzene). Place the slide over a low temperature hot plate (50 to 60°C). Make from defibred sample a fibre suspension of about 0.05 percent. Place about 0.5 ml of this suspension on the centre of the ruled slide. The ruled lines will keep the fibre within marked area. As the water evaporates, tap the slide gently and arrange the fibres with a needle. After drying, cool the slides and stain with Graff 'C' stain and place a 25 mm^2 cover slip on it. The slides are now ready to be observed under the microscope.

NOTE — Remove dust or lint with a clean dry brush before placing the slides on hot plate and avoid touching of the fibres on the slides with the fingers.

8 STAINING

8.1 Apply two to three drops of Herzberg or 'C' stain to the fibres on the slide and place the cover slip over it with care to avoid inclusion of air bubbles. Allow the slide to stand for 1 to 2 min. Remove the surplus stain from the slides by using blotting paper. The slides, are now ready for examination.

8.2 For staining with Lofton Merrit stain, cover the fibres on the slide with three drops of the stain and allow to stand for 2 min. Remove the excess stain with a piece of filter paper and apply a few drops of 0.1 percent hydrochloric acid. After about 30 s remove excess of the acid and add a few drops of water. Finally place a cover slip in position, apply gentle pressure with a pair of needles and carefully drain the surplus water.

8.3 For proper diffrentiation of colours in fibre analysis it is recommended that a 60 W frosted electric lamp or an equivalent 'day light' fluorescent lamp be used at all times with the light source placed 25 to 30 cm from the mirror of the microscope. The light source and reflecting mirror be so adjusted that the light is not too bright, otherwise colour judgement is difficult. The colour reaction with the stain are, of course, not permanent. The slides, therefore, should be examined immediately after staining and in no case an attempt at judgement should be made more than an hour after staining.

8.4 The colours developed vary according to the stain employed, the nature of the raw material and the process used for reducing this to pulp. The colours to be expected from Herzberg stain and 'C' stain are given in Annex A, but the analyst should check known pulp samples from different raw materials to become familiar with their exact colour. Both the stains generally give a yellow colour to mechanical or ground wood pulp and red colour to Rag and Hemp while chemical pulp is stained bluish or purplish grey. The colours developed with Herzberg stain are comparatively deeper but structural details are usually seen more clearly with 'C' stain.

8.5 It is rather difficult to indicate the exact colours to be obtained with different stains and pulp by descriptive terms only. Therefore, to eliminate confusion during comparison and matching, the range of colours to be expected in each case is given in Annex A, according to the British Colour Council Dictionary of Colour Standards 1951, together with their reference numbers.

9 SLIDE CLEANING SOLUTION

The mixture of 50 ml ethyl alcohol, 50 ml water and 1 ml concentrated hydrochloric acid (36 percent), is found to be very effective for final cleaning of slides and cover glasses.

10 QUALITATIVE IDENTIFICATION

10.1 Examination of the Slide

Place the stained slide in position on the mechanical stage of the microscope. For illumination, a 15 W day light fluorescent tube placed 25 to 30 cm from the mirror of the microscope is recommended. Observe the colours of the various types of fibres, slowly moving the slide backward and forward as well as side ways so that the entire mount is fully covered. Compare the colours observed for the different fibres with those given in Annex A.

10.2 Note carefully the morphological peculiarities of the differnt constituents, such as shape and size of the cells, wall thickness, width and nature of lumen, shape, size, frequency and type of pitting and characteristic markings like striation, nodes, etc. Compare these with those of known fibres given in Annex B.

10.3 From a careful anaylsis of the staining reactions and morphological characteristics, it should be possible to fix the identity of the different constituents in any pulp sample with a fair degree of accuracy. In case of doubt compare with standard slides of pulps of known composition.

10.4 Spot Stain for Groundwood

It is often desirable in the plant or laboratory to detect merely the presence or absence of groundwood. No microscopic examination is necessary. The stain is simply applied to the paper and the colour observed. Standards containing various percentages of groundwood and other pulps may be prepared and used as a basis of comparison for these spot stains.

NOTE — In using stains for application to the surface of paper, it should be remembered that many of the dyes used for colour papers are sensitive to acids and colour change, while apparently showing the presence of groundwood, may be caused by the action of the acid on the dye-stuff. For coloured papers, in case of doubt, it is advisable to run a blank test with a little dilute acid. Cheque papers require particular case in this respect. In some cases, it may even be necessary to remove the dye (*see* **6.3.6**).

10.4.1 *Phloroglucinol Stain*

This stain produces a bright red or magenta colour with groundwood. The depth of colour is an indication of the amount of groundwood present. A very light colour, however, does not necessarily prove its presence, as partly cooked jute, partly cooked unbleached chemical pulp and some other liquified fibres are also slightly coloured. In many cases, jute papers show a deep colouration with this stain. Especially in the case of strong papers, indication of groundwood should be confirmed microscopically.

10.4.2 *Aniline Sulphate Stain*

This solution produces a yellow colour on papers containing a considerable percentage of groundwood. It is not quite sensitive as phloroglucinol but is easy to prepare with less costs.

10.4.3 *Lofton Merrit Stain*

This stain may be applied either to fibres on the slide or to fibres in a beaker (when staining in beaker, add 1.5 g fibre to a mixture of 15 ml of solution A and 20 ml of solution B and 0.09 ml of concentrated HCl (*see* **5.4**). This stain is effected by the amount of lignin present. If the pulp is free from lignin, the fibres will be colourless. If the pulp is highly lignified they will stain blue. All stages in between will depend upon the degree of delignification. Unbleached sulphite pulp has a tendency to give more intense red colour than unbleached kraft. Therefore, this stain has some value for their differentiation. However, any special treatment given to pulp may interfere with the test and hence it should be used only as an indication of the presence of unbleached kraft or unbleached sulphite and not as a conclusive test.

11 MICROSLIDE EXAMINATION

The methodical examination of prepared microslides varies with fibre analysts. Nevertheless, all routine analysis should provide for a systematic study of entire slide area. In addition, a practice of periodically switching the objective lenses back and forth from low to higher magnification along with the movement of mechanical stage for proper focussing of slide is necessary in order to make observation on finer details. For systematic examination of fibre slide following steps should be followed:

i) Locate the ocular pointer or scale about 2 - 3 mm from the corner of the cover glass. Note the position of the mechanical stage along its *Y*-axis.

ii) Slowly move the slide in a horizontal direction (*X* - axis) across the fibre field (at each point of interest, fibre fragments, cells as needed, move the slide vertically, also increase the viewing

magnification, after such action, return to the lower magnification and move the slide to the original vertical position selected for that particular traverse) and then make another traverse in opposite direction. Continue this pattern until the entire cover glass has been examined.

12 QUANTITATIVE ANALYSIS

12.0 The quantitative analysis consists of assigning mass percent to different fibres in a composition. The first is microscopical examination of prepared slide and count of types of the fibres observed. The second basic operation in quantitative analysis is the conversion of counting data to a form that can be used to calculate mass. This conversion is accomplished through the use of mass factors.

12.1 Mass Factor Determination

The following two methods are used to count number of fibres on the slide:

i) Pointer Method, and
ii) Square Method.

12.1.1 *Pointer Method*

Place the stained slide in position on the stage of the microscope. Move the pointer with the mechanical stage so that the pointer is 2-3 mm from the top corner of the cover glass. Move the field horizontally, count and the fibres of each kind and record as they pass the pointer. Alternatively separate passes may be made for each kind provided care is taken to see that the slide is not shifted even to the slightest extent either upward or downward. When all the fibres in one line had been counted, move the stage 5 mm vertically, and count the fibres counted in second line. Count the fibres in five different lines each 5 mm apart. If a single fibre passes the pointer more than once, count it each time. If the fibre follow the centre for some distance, count it as only one fibre. Ignore fragments below 100 micron but add together mentally large fragments as equivalent to a whole fibre.

12.1.2 *Square Method*

For ease of counting, divide the cover glass into nine equal squares. Stain the fibres with 'C' stain and count the total fibres of each kind appearing in each square and add up for all the nine squares.

After assigning an arbitrary value of unity for Rag, determine the mass factor of the given pulp by the above two methods. Within experimental error and tolerance allowed, both the methods relate well to each other and give similar values for mass factor. However, for practical purposes the pointer method is more quick and hence this method may be followed for subsequent determination.

12.1.3 *Mass Factor*

When an equal mass of pulp from two different types of fibres are thoroughly mixed and standard slides prepared, it is observed that fibres of one type may be encountered much more frequently than those of other type. This situation implies that the morphology and wall thickness of the two fibre sources differ and that one source has more fibres per unit mass of pulp. If one wishes to calculate the mass proportions of these two fibre types from microscopical data (that is, fibre number) then a conversion factor is required which is called a pulp mass factor.

The mass factor is a dimensionless number derived for a given pulp type by comparing the number of fibres per unit mass to the number of fibres per unit mass of a reference pulp. However, reference pulp taken in use is a particular reference pulp of Rag and cotton linters. Although it is claimed that the use of fibre coarseness values (mass/unit length) would be more accurate than that of mass factors since no reference fibre is required.

12.1.4 *Calculation of Pulp Mass Factors*

12.1.4.1 Weigh out approximately equal proportions of a reference pulp and a pulp to be characterized to the nearest 0.000 1 g (pulps should be oven dry).

12.1.4.2 Blend the two samples thoroughly in water, being careful not to promote a reduction in fibre length.

12.1.4.3 Prepare slides for microscopical examination.

12.1.4.4 Identify (via staining or morphology) the number of each of the two fibre types. Use a combined total of at least 300 fibres.

12.1.4.5 Calculate the mass factor WF_x of the unknown fibre as follows :

$$WF_X = WF_R \times \frac{N_R W_X}{N_X W_F}$$

where

WF_x = mass factor of unknown fibre,
WF_R = mass factor of reference pulp,
N_R = Number of reference fibres counted,
W_x = mass in g of unknown fibre,
N_x = Number of unknown fibres counted, and
W_F = mass in g of reference fibre.

Mass factors are given in Table 1.

NOTE — The mass factors were determined at the Forest Research Institute, Dehra Dun and Central Pulp and Paper Research Institute, Saharanpur from pure samples of pulp of different fibrous raw materials commonly used in the country for the manufacture of paper and board. For any particular species the mass factor largely depends on the size of elements included in the fibre count. The mass factor, however, is not affected to any appreciable extent by the cooking process.

12.2 Determination of Fibre Length and Diameter

Place the slide under a microscope equipped with a graduated mechanical stage, and a 16 mm objective.

When length only is to be measured use any one of the different types of eye piece micrometer scale. If width is to be determined, preferably micrometer eye piece should be used. Measure each fibre with a micrometer to the nearest half division in the scale and record the figures. A minimum of 200 measurements shall be made and if this number is not on the original slide, extra slides shall be made for the determination of fibre length and fibre diameter. Prepare the slides at consistency lower than 0.012 5 percent *(see* **12.3).**

NOTE — A 0.008 percent consistency has been found suitable for the determination of fibre dimension because at this consistency no more than 75 fibres get distributed on the slide and it is easy to determine the dimensions of each fibre appearing on the slide.

12.3 Selection of Proper Consistency of Fibre Suspension for the Preparation of Slides of Monocotyledons Fibrous Raw Material

0.05 percent consistency of fibre suspensions for the preparation of slide holds good for conifers, hardwoods and dicotyledons type of fibres. However, the same consistency used for monocotyledons (it represents bamboo, bagasse, wheat straw, rice straw and grasses, etc), which are mostly indigenous fibre sources, may result in dense slides and hence difficult to examine each fibre. A 0.012 5 percent consistency of fibre suspensions has been found to be most suitable for the preparation of slide from monocotyledon fibrous sources because it fulfills the basic requirement of a properly prepared slide, where the fibres are distributed evenly at low density on the slide for examination of individual fibre.

Table 1 Mass Factor of Different Pulps
(*Clause* 12.1.4.5)

Sl No.	Fibre	Mass Factor
(1)	(2)	(3)
i)	Rag	1.0
ii)	Imported coniferous (unbleached and bleached sulphate)	1.04
iii)	Indian spruce (Mechanical)	1.40
iv)	Jute (unbleached)	1.40
v)	Hemp (unbleached soda)	1.13
vi)	Salai (unbleached and bleached sulphate)	1.16
vii)	Salai (unbleached and bleached mechanical)	1.40
viii)	Eucalyptus threticornis (unbleached)	0.30
ix)	Eucalyptus threticornis (bleached)	0.28
x)	Bamboo (unbleached, bleached sulphate, sulphite, soda)	0.78
xi)	Bagasse (unbleached/bleached)	0.75
xii)	Wheat straw (unbleached)	0.69
xiii)	Wheat straw (bleached)	0.55
xiv)	Rice straw (unbleached)	0.47
xv)	Rice straw (bleached)	0.43
xvi)	Sabai grass (unbleached, bleached soda)	0.48
xvii)	KHAR grass (bleached)	0.43
xviii)	KAHI grass (bleached)	0.44
xix)	Jute stick (unbleached sulphate)	0.40

12.4 Determination of Length and Width of Various Morphological Parts of a Fibrous Raw Material

Length and width of various morphological parts of the different pulp is determined to use it as a diagnostic feature of the pulp when present in unknown furnish. Since these morphological parts, namely, parenchyma cells, epidermal cells, and vessels are sometimes very small, it is necessary to use high magnification for the determination of their dimensions.

12.5 Stain the fibres with 'C' stain and examine under a projection microscope. For ease of measurement, use a PIRA fibre length counter. Carry out measurement for fibre length, fibre diameter, and cell dimensions at the magnification given below:

Particular	*Magnification*
Fibre length	×50
Fibre diameter	×125 ×480
Parenchyma cells, Vessel, epidermal cells, etc	×125 ×480

Data available for fibre dimensions, cell dimensions, special features for different pulps are given in Table 2.

13 REPORT

The proportion of the various fibres found in the samples shall be reported in terms of the percent by mass of the total fibre composition to the nearest whole number followed by an expression of the accurracy of the given figure. Thus if the calculated percent is 47.6 and from two or more observations the analyst can reasonably conclude that this figure is not likely to differ from the actual percent by more than 5 percent the report should read 48 ± 5. Percentages of less than 2 shall be reported on traces. In case of doubt or dispute the mass factors used should be indicated in the report.

14 PRECISION

14.1 The precision depends upon the skill and experience of the analyst and use of the correct mass factors. An experienced and accurate worker may be expected to determine the composition of a furnish that is not too complex within the following tolerances:

Percentage of Given Fibre in Total Furnish	*Tolerance*
Less than 20	± 2
20 and above but less than 30	± 3
30 and above but less than 40	± 4
40 and above but less than 60	± 5
60 and above but less than 70	± 4
70 and above but less than 80	± 3
80 and above	± 2

Table 2 Diagnostic Feature of Different Pulps

(*Clause* 12.5)

All Figures in Micron.

Sl No.	Pulp	Fibres		Parenchyma		Vessels		Epidermal Cells	
		Length	Width	Length	Width	Length	Width	Length	Width
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	Rag	2 900 (780-8 000)	24 (10-34)	—	—	—	—	—	—
ii)	Imported coniferous (chemical)	3 000 (800-6 500)	45 (20-30)	—	—	—	—	—	—
iii)	Spruce (mechanical)	Incomplete	40 (30-60)	—	—	—	—	—	—
iv)	Jute (unbleached)	2 000 (1 500-5 000)	20 (10-25)	—	—	—	—	—	—
v)	Hemp (Rope cutting)	6 000 (3 000-21 000)	20 (10-30)	—	—	—	—	—	—
vi)	Salai (chemical)	850 (350-1 300)	25 (15-45)	120 (40-320)	35 (20-70)	470 (250-830)	170 (70-280)	—	—
vii)	Salai (mechanical)	Incomplete	25 (15-45)	—	—	—	—	—	—
viii)	Eucalyptus tereticornis	900 (400-1 600)	12 (6-30)	69 (30-160)	23 (15-40)	360 (200-500)	140 (70-200)	Absent	Absent
ix)	Bamboo	2 100 (400-5 000)	15 (5-40)	110 (30-500)	35 (10-60)	650 (150-1 200)	120 (40-250)	—	—
x)	Bagasse	1 750 (250-4 000)	23 (10-60)	375 (100-900)	100 (30-180)	600 (180-1 600)	100 (30-220)	—	—
xi)	Wheat straw	1 300 (600-4 520)	13 (8-25)	237 (83-300)	50 (20-100)	240 (188-292)	61 (21-100)	116 (30-250)	18 (6-30)
xii)	Rice straw	1 100 (600-4 200)	7 (4-15)	123 (30-200)	18 (8-30)	51 (17-170)	50 (30-180)	135 (30-300)	10 (6-20)
xiii)	Sabai grass	1 500 (600-4 000)	9 (5-15)	70 (30-220)	15 (10-50)	—	30 (15-45)	—	—
xiv)	KHAR grass	1 500 (680-4 600)	9 (4-20)	100 (40-420)	22 (10-50)	149 (60-230)	49 (30-75)	73 (58-100)	16 (10-20)
xv)	KAHI grass	1 500 (700-4 700)	8 (4-15)	143 (30-380)	32 (10-73)	200 (52-560)	65 (30-100)	123 (25-210)	11 (6-20)
xvi)	Jute stick	700 (300-1 250)	30 (15-50)	90 (30-220)	30 (13-52)	400 (150-800)	80 (30-140)	—	—

14.2 To achieve the precision as given in **14.1,** examination of authentic pulp mixtures from time to time by the analyst is essential so as to ensure that sound judgement is exercised in the proper categorization of the fibres and also in including or rejecting fragments and debris in the count. Under ideal conditions it may even be possible for the experienced analyst to check the composition of a furnish within half the limits mentioned, if mass factors of the actual pulps and in the furnish are determined and used.

ANNEX A

(*Foreword* and *Clauses* 8.4, 8.5 *and* 10.1)

COLOUR REACTION OF DIFFERENT PULPS

Sl No.	*Pulp*	*Herzberg Stain*	*'C' Stain*
(1)	(2)	(3)	(4)
i)	Rag	Crushed strawberry (B.C.C. 158)	Old Rose (B.C.C. 157) to crushed strawberry (B.C.C. 158)
ii)	Imported coniferous (unbleached, and bleached sulphate or sulphite)	Dark grey with a purplish tinge ranging from gun metal (B.C.C 42) to graphite (B.C.C. 155)	Light grey ranging from oyster grey (B.C.C. 31) and gull grey (B.C.C. 81) to platinum (B.C.C. 152) and violet grey (B.C.C. 41)
iii)	Spruce (mechanical)	Bright yellow ranging from Butter cup (B.C.C. 53) to Bunting yellow (B.C.C. 113)	Light yellow ranging from chartreuse yellow (B.C.C. 75) to primrose (B.C.C 111)
iv)	Hemp (unbleached soda)	Crushed strawberry (B.C.C. 158) to Raspberry (B.C.C. 158)	Crushed strawberry (B.C.C. 158) to Peony red (B.C.C. 37)
v)	Salai (unbleached and bleached sulphate)	Dark grey ranging from steel blue (B.C.C. 44) to gun metal (B.C.C. 42)	Bluish grey ranging from steel blue (B.C.C. 44) to slate grey (B.C.C. 154)
vi)	Salai (unbleached and bleached mechanical)	Bright yellow ranging from Butter cup (B.C.C. 53) to Bunting yellow (B.C.C. 113)	Light yellow ranging from chartreuse yellow (B.C.C. 75) to Primrose (B.C.C. 111)
vii)	Eucalyptus tereticornis (unbleached and bleached)	Dark blue ranging from vixtrix blue (B.C.C. 47) to oxford blue (B.C.C. 49) and blue black (B.C.C. 50)	Bluish grey ranging from steel blue (B.C.C. 44) to slate grey (B.C.C. 154)
viii)	Bamboo (unbleached and bleached soda, sulphate or sulphite)	do	do
ix)	Bagasse (unbleached/bleached soda)	do	do
x)	Wheat straw (unbleached/bleached)	do	do
xi)	Rice straw (unbleached/bleached)	do	do
xii)	Sabai grass (unbleached/ bleached)	Dark blue ranging from vixtrix blue (B.C.C. 47) to oxford blue (B.C.C. 49) and blue black (B.C.C. 50)	Bluish grey ranging from steel blue (B.C.C. 44) to slate grey (B.C.C. 154)
xiii)	KHAR grass (unbleached/ bleached)	do	do
xiv)	KAHI grass (unbleached/ bleached)	do	do
xv)	Jute stick (unbleached/sulphate)	Light grey ranging from platinum (B.C.C. 152) to silver grey (B.C.C. 153) and violet grey (B.C.C. 41)	Pale bluish grey ranging from sky grey (B.C.C. 161) to powder blue (B.C.C. 193)

ANNEX B

(*Foreword* and *Clause* 10.2)

MORPHOLOGICAL CHARACTERISTICS

B-1 GENERAL

Morphological characteristics are of great diagnostic value in distinguishing under a microscope the fibrous materials commonly used for pulp and paper manufacture. However, the features are sometimes liable to be somewhat obscured or altered as a result of the mechanical and chemical processes to which the raw materials are subjected during pulping. Occasionally some new structural peculiarities may arise as in the case of bamboo where the compressed areas with transverse marking which constitute a striking feature of the fibres, are found only in the pulp, but not in the unprocessed material. Further the extent and manner of breakdown or separation of the different cellular constituents in the pulp also depend upon the pulping processes used. In groundwood pulps or mechanical pulps which are produced from logs by a mechanical grinding process, the separation is incomplete. Such pulps consist of broken fragments of

fibres and bundles of fibres with associated non-fibrous elements torn away from the wood. The disintegrated fragments still retain their lignin and other compounds which serve to hold or cement the cells together. The various chemical processes on the other hand involve the penetration of small chips of the raw materials by a solution, the digesting liquor, which dissolves the cementing substances by removing the lignin. As a result, individual elements of the different cellular constituents like tracheids, Fibres, parenchyma, vessels, etc, are completely separated, there being no torn or broken fragments of tissue. Morphological characteristics of different pulps commonly used in India are described below, and the imported diagnostic features summarized for easy reference and use in Table 2.

B-2 RAG PULP

Cotton (*Gossypuum* spp.) and linen or flax *(Linum usitatissimum)* fibres are usually designated together as 'rag', as often their distinguishing features are not easy to make out in pulp samples, due to having undergone considerable treatment. However, unlike in Western countries where rag pulp usually comprises both cotton and linen fibres, in India rag consists almost entirely of cotton fibres. The description given here is, therefore, applicable only to cotton fibres. Identification of cotton fibres under a microscope should not ordinarily present much difficulty on account of their distinctive staining reaction and unique morphological characteristics. Being a seed hair, cotton fibres are always torn and jagged at one end (base) and somewhat rounded at the other. The individual fibres are long, flat and ribbon-like, and more or less twisted on the longitudinal axis as shown in Fig. 1. The average length of the fibres varies considerably in different species and varieties ranging from about 20 mm in some of the coarse Indian varieties to about 48 mm in the sea island cotton. However, in rag pulp complete fibres are rarely found and the average length in Indian rag pulp examined was found to be only 2 900 micrometer with a range of 780 to 8 000 micrometer. The width of the fibres in indigenous rag ranges from about 10 to 34 micrometer with an average of 24 micrometer. The fibres often show characteristic longitudinal and spiral striations.

B-3 IMPORTED CONIFEROUS PULP

Imported coniferous pulps are made from a number of softwood species like pine, spruce, douglas fir and fir. Morphological characteristics of these species are shown in Fig. 2. Being chemical pulps, the individual cells are usually completely separated, there being no broken fragments of cellular tissue. The tracheids constitute the bulk of the cells in the pulp, parenchyma (ray) cells being relatively few. The tracheids vary in length from about 800 to 6 500 micrometer with an average of 3 000 micrometer, while the width ranges from 20 to 80 micrometer with an average of about 45 micrometer. The broad, thin-walled, earlywood tracheids are usually characterized by a single row of large bordered pits and cross-field showing 1 -6 generally smaller pits. The number, shape and size of the cross-field pits in the earlywood tracheids are often useful in separating the various softwood species used in imported pulps. The thicker-walled latewood tracheids are somewhat narrower, with a considerably reduced lumen and fewer pits. The parenchyma cells from the ray tissue are short, rectangular and thin-walled with a few relatively small pits. Pronounced spiral thickening in all the tracheids is a characteristic feature of douglas fir pulp.

B-4 SPRUCE PULP

Indian spruce (*Picea smithiana*) is used mostly for mechanical pulp. Spruce mechanical pulp is very similar to salai groundwood pulp as described in **B-7** in the sense that it consists entirely of small to large fragments of torn cellular tissue as shown in Fig. 3. However, it can be readily distinguished from salai mechanical pulp by the absence of vessels and the characteristics pitting of the fibrous longitudinal elements which are known as tracheids. The length of the tracheids cannot be determined in the mechanical pulp on account of their broken and torn condition. But they are nearly twice as broad as the fibres of salai measuring about 30 to 60 micrometer (average 40 micrometer) in width and show large bordered pits usually arranged in a single row. The pits occurring in the area of contact between the tracheid and ray parenchyma cells or cross-field as it is commonly known, are smaller with narrow, linear and slightly extended aperture. This type of cross-field pitting is described as piccoid. Some of the tracheids show spiral thickening.

B-5 JUTE

The jute (*corchorus* spp.) fibres are obtained from the bark of twigs by setting and used in the manufacture of all kinds of cultural and industrial paper of varying quality. The pulp consist of fibres only. The fibres are comparatively shorter than hemp and are cylindrical in shape. The fibre walls are smooth with occasional nodes or cross marks while the diameter of the fibres show little variation. The lumen which is usually broad varies greatly in different parts of the same fibre. The fibres occur in bundles occasionally as shown in Fig. 4. The fibres are 1.5 to 5 mm in length, average 2 mm and 10-25 micrometer in width with an average of 20 micrometer.

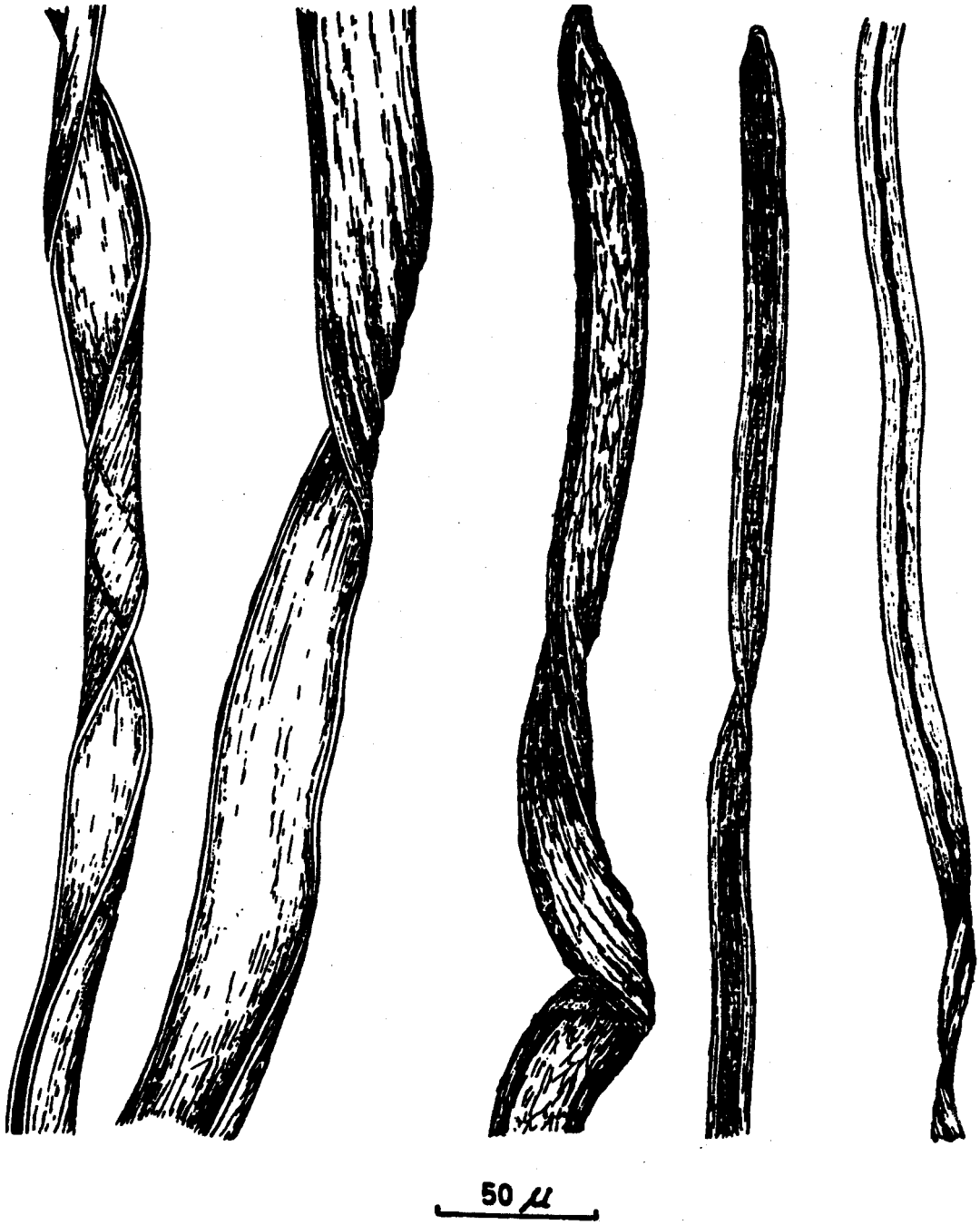


FIG. 1 MORPHOLOGICAL CHARACTERISTICS OF RAG PULP

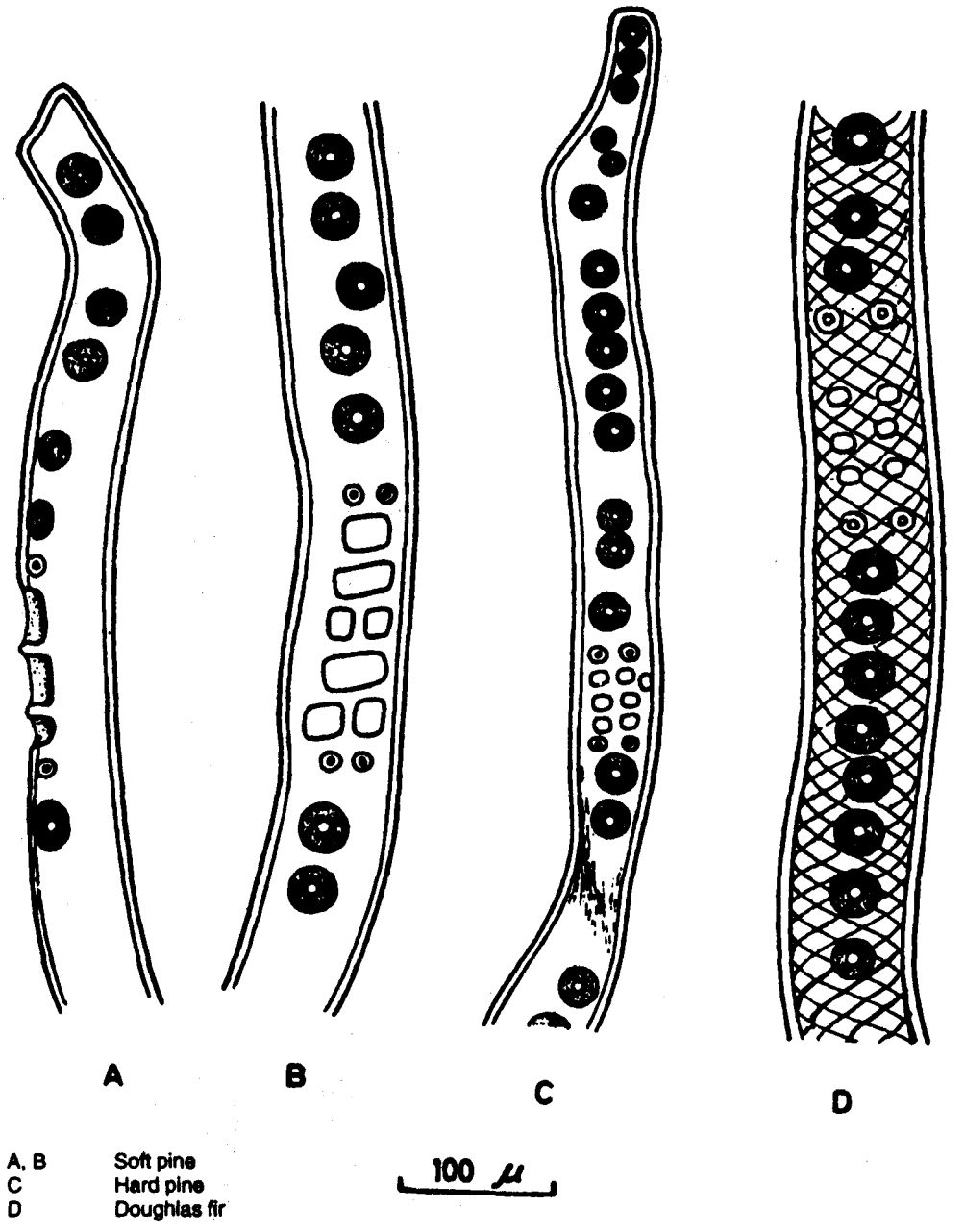
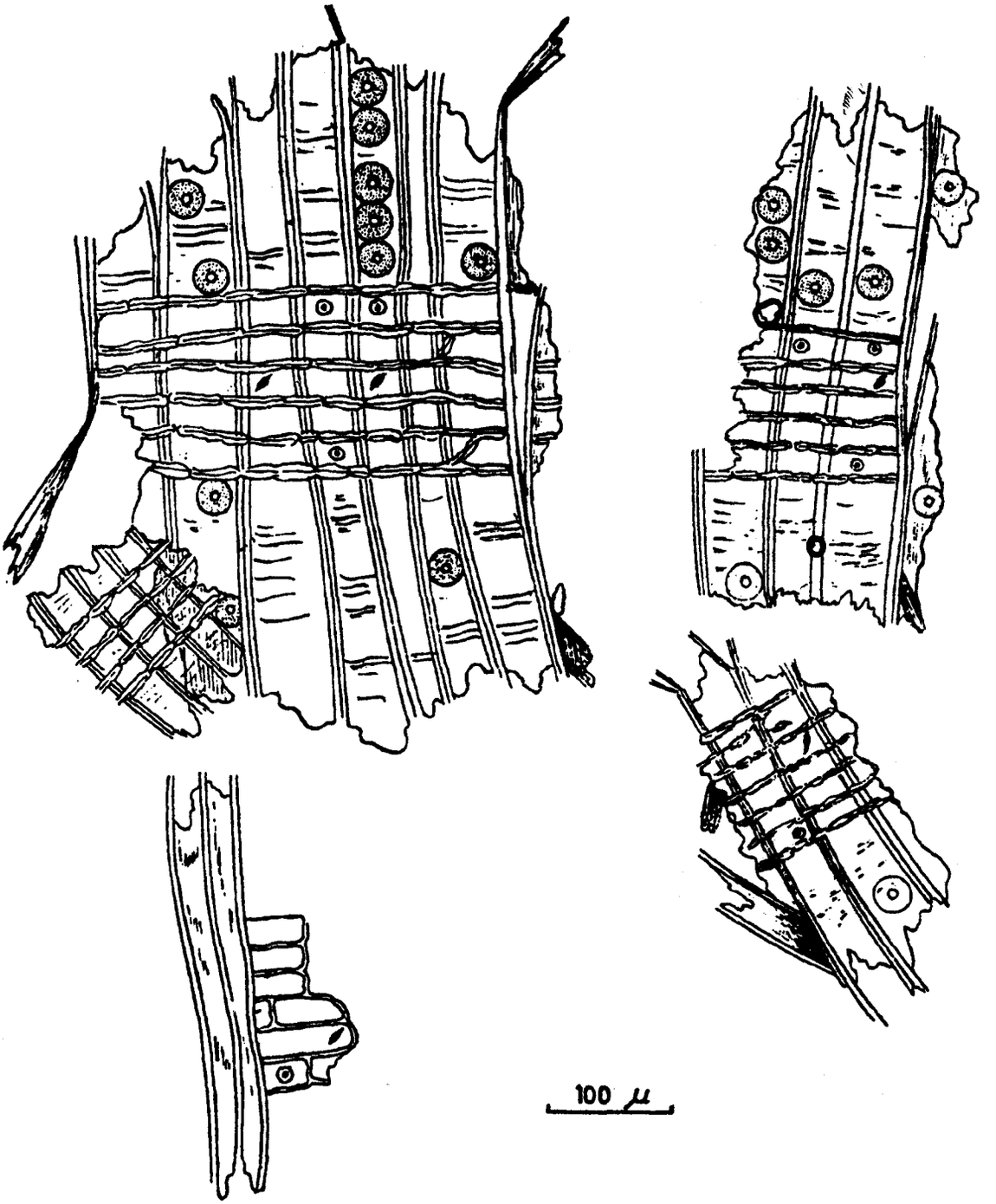


FIG. 2 MORPHOLOGICAL CHARACTERISTICS OF IMPORTED CONIFEROUS (CHEMICAL) PULP



Fragments of tracheitis with large bordered pits in a single row with attached ray parenchyma.

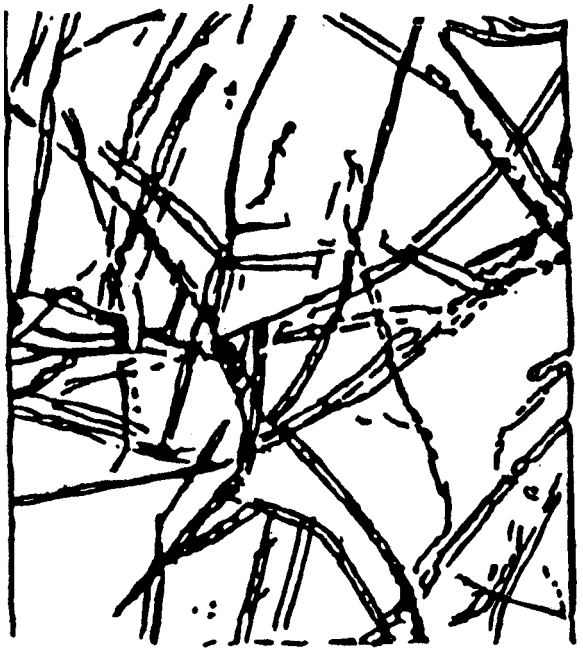
FIG. 3 MORPHOLOGICAL CHARACTERISTICS OF SPRUCE (MECHANICAL) PULP

B-6 HEMP PULP

Though somewhat similar to rag pulp in its staining behaviour, pulp obtained from hemp (*Cannabis sativa)* rope cuttings can be easily distinguished by the morphological characteristics given below and shown in Fig. 5. The individual fibres when complete are very long measuring from 5 to 50 mm with an average of 20 mm, and moderately wide ranging from 7 to 50 micrometre with an average of 22 micrometre. However, most of the fibres may be cut, the length varying from 3 to 21 mm with an average of 6 mm. The width may vary from 10 to 30 micrometre with an average of 20 micrometre. The fibres are moderately thin to thick-walled, the lumen being not uniform in width, which may be equal to or greater than the wall thickness. They do not exhibit any twist, but joints or compressed areas with transverse fractures, longitudinal striations and somewhat swollen fissures are conspicuous. The tips of the fibres are typically blunt and rounded at both ends and sometimes forked. Fragments of parenchymatous tissue are occasionally attached to the fibres.

B-7 SALAI PULP

Salai *(Boswellia serrata)* is a hardwood which is used in India both for chemical and mechanical pulp. Salai pulp, like all hardwood pulps, exhibits a greater diversity of cell types than softwood pulps like indigenous spruce mechanical pulp or imported coniferous chemical pulp described in **B-3** and **B-4** respectively. The morphological characteristics of salai (chemical) and salai (mechanical) pulp are shown in Fig. 6 and 7 respectively. In the chemical pulp, as already mentioned, the different cellular constituents of wood are usually completely separated due to the dissolution of the middle lamella or the intercellular or cementing substance and fragments of



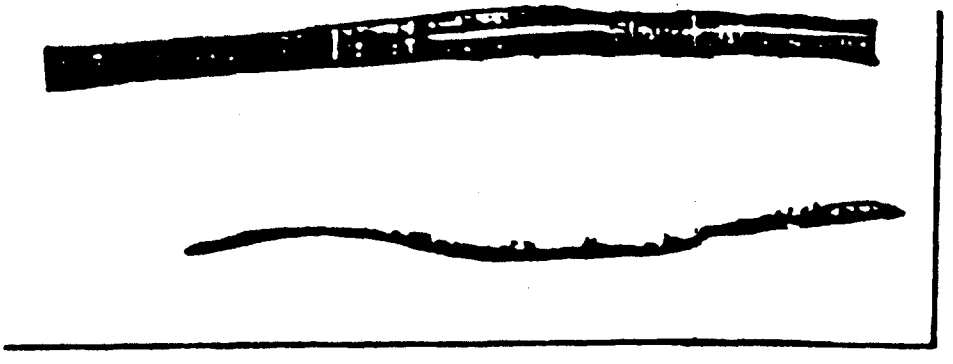


FIG. 4 MORPHOLOGICAL CHARACTERISTICS OF JUTE PULP

torn tissue are entirely absent. The individual fibres measures 350 to 1 300 micrometre (average 850 micrometre) in length and 15 to 45 micrometre (average 25 micrometre) in width, with a relatively broad middle region and somewhat abrupt to gradual, tapering, pointed ends and are sometimes separate. The fibre wall is 3 to 6 micrometre thick and moderately pitted, the pits showing a vertical slit-like aperture which usually extends to and beyond the border which may be round to oval. The parenchyma cells are comparatively few, 40 to 320 micrometre (average 120 micrometre) in length and 20 to 70 micrometre (average 35 micrometre) in width, with numerous simple pits. Vessel elements vary from 250 to 830 micrometre (mean 470 micrometre) in length and from 70 to 280 micrometre (mean 170 micrometre) in diameter. Intervessel pits are numerous, large 7 to 11 micrometre in diameter with rounded to oval or hexagonal border through crowding, with linear to lenticular horizontal aperture. Pits leading to parenchyma are often larger with a long horizontal orifice 12 to 15 micrometre in length. In the mechanical pulp as the middle lamella remains intact, there is no separation of individual elements. The pulp accordingly shows only fragments of broken fibres and torn groups of fibres with the associated parenchyma and vessels, which may vary considerably in size and shape. Though the exact dimensions of the various elements like fibres, parenchyma and vessels cannot be determined, other morphological characteristics are similar to those observed in the chemical pulp and are useful in establishing the identity of the pulp.

B-8 EUCALYPTUS PULP

Eucalyptus tereticornis is a hardwood which is used in India both for chemical and mechanical pulp. Eucalyptus pulp like all hardwood pulps, exhibit a greater diversity of cell types than softwood pulp like indigenous spruce or imported coniferous chemical and mechanical pulps. In the chemical pulp, the different cellular constituents of wood are usually completely separated due to the dissolution of the middle lamella or the intercellular cementing substance (that is, lignin) and fragments of torn tissue are entirely absent. The individual fibres measure 400 to 1 600 micrometre (average 900 micrometre) in length and 6 to 30 micrometre (average 12 micrometre) in width, with a relatively broad middle region and somewhat abrupt to gradual tapering pointed ends and are sometimes separated. The fibre is pitted. The parenchyma cells with numerous pits measure 30 to 160 micrometre (average 69 micrometre) in length and 15 to 40 micrometre (average 23 micrometre) in width. Vessel elements vary in length from 200 to 500 micrometre (average 360 micrometre) and 70 to 200 micrometre (average 140 micrometre) in width (*see* Fig. 8.)

B-9 BAMBOO PULP

Several species of bamboo are used for manufacture of pulp and paper. The more important and common among these in India are *Dendrocalamus strictus, Bambusa arundinacea* and *Melocanna bambusoides* which, however, cannot be distinguished under the microscope, when pulped. Bamboo pulp, unlike rag pulp consists not only of fibres but a number of other cell types like parenchyma or pith cells, vessel elements and epidermal cells as shown in Fig. 9. The length of the fibres as determined from a large number of pulp samples, received from various paper mills in the country varies from about 400 to 5 000 micrometre with an average of 2 100 micrometre while the width ranges from 5 to 40 micrometre with an average of about 15 micrometre. The fibres are uniformly thick to thin-walled, with gradually tapering pointed ends, smooth walls, narrow to wide lumen and very sparse slit-like pits. They are often bent, curved or folded and invariably show compressed, somewhat buckled areas with transverse markings, which stand out rather prominently in the thick-walled fibres. The walls, sometimes may be as much as 10 micrometre thick often showing a distinct lamellated or multi-layered structure. The parenchyma cells are fairly abundant. They are squarish to rectangular in shape, varying from about 30 to 500 micrometre (average 110 micrometre) in length and from 10 to 60 micrometre (average 35 micrometre) in width. Vessel elements with numerous pits are usually present. They may be short and discoid or barrel shaped, or long and cylindrical with truncated or tailed ends and simple or scalariform perforations. They vary in length from about 150 to 1 200 micrometre (average 650 micrometre) while the diameter ranges from 40 to 250 micrometre (average 120 micrometre). Epidermal cells are rare, rectangular in shape usually with straight to somewhat wavy margins.

B-10 BAGASSE PULP

The pulp from sugar cane (*Sachharum officinarum)* residue, commonly known as bagasse shows the same diversity of cell types as bomboo pulp as shown in Fig. 10. The fibres are up to 4 000 micrometre in length with an average of about 1 750 micrometre and 10 to 60 micrometre in width with an average of 23 micrometre. They are thick to thin-walled, usually with straight, pointed ends and relatively more numerous slit-like or lenticular pits than in bamboo. Transverse markings similar to those of bamboo are quite common. The wider fibres are usually shorter and comparatively thin-walled not frequently with blunt, oblique or forked ends. Parenchyma cells are very abundant, usually appreciably larger than those of bamboo. They are up to 900 micrometre in length with an average of about 375 micrometre and up to 180 micrometre in width with an average of

100 micrometre, and serve to easily distinguish bagasse from bamboo. Vessels are similar to those of bamboo, ranging from 180 to 1 600 micrometre (average 600 micrometre) in length and 30 to 220 micrometre (mean 100 micrometre) in width. Epidermal cells somewhat narrow and rectangular with undulating margins are always present but not very common. Stomata may also be rarely present.

B-11 WHEAT STRAW

Pulp made from wheat straw is somewhat similar to rice straw and bagasse in general characteristics comprising of the same kind of cells, that is, fibres, parenchyma, vessels and epidermal cells. The fibres are remarkably uniform and straight with rather thick wails and sharp pointed tapering ends. The fibres vary in length from 600 to 4 520 micrometre (average 1 300 micrometre). In width they are very much narrower than bagasse ranging mostly from 8 to 25 micrometre (average of 13 micrometre) and at once serve to distinguish wheat straw from the bagasse. Rectangular and barrel shaped parenchyma cells are abundant and often present in masses/ individuals. They range from very small to large measuring 83 to 300 micrometre (average 237 micrometre) in length and 20 to 100 micrometre (average 50 micrometre) in width. Vessels are fairly long but very much narrower in width than bagasse varying from 21 to 100 micrometre (average 61 micrometre) (*see* Fig. 11). Epidermal cells are always present either as masses/individuals comparatively more numerous than in bagasse, rectangular in shape with characteristic, toothed margin. They range from 30 to 250 micrometre with average of 116 micrometre in length and from 6 to 30 micrometre with an average of 18 micrometre in width. Spicules of various sizes and shapes are also found.

B-12 RICE STRAW

Rice straw resembles wheat straw and bagasse in the cell types which are present but differs from them chiefly in size of the elements. The fibres are thin and slender than wheat straw but shorter in length. The length varies from 600 to 4 200 micrometre (average 1 100 micrometre) and width from 4 to 15 micrometre (average 7 micrometre). Rectangular and barrel shaped parenchyma cells are numerous, present either in masses/individuals. They are smaller than those of wheat straw measuring 30 to 200 micrometre (average 123 micrometre) in length and 8 to 30 micrometre (average 18 micrometre) in width. Vessel segments measure up to a maximum length of 170 micrometre to a minimum of 17 micrometre (average 51 micrometre). Epidermal cells are abundant appearing as masses/individuals like in wheat straw with sharp toothed edges on either sides or one side. They range from 30 to 300 micrometre (average 135 micrometre) in length and from 6 to 20 micrometre (average 10 micrometre) in width (*see* Fig. 12).

B-13 KHAR GRASS

The morphological feature of khar grass are similar to those of rice straw, wheat straw and sabai grass. The fibres are uniform, long and slender with a length close to sabai grass ranging from 680 to 4 600 micrometre (average 1 500 micrometre). The width of the fibres varies from 4 to 20 micrometre (average 9 micrometre). Parenchyma cells are abundant and rectangular to barrel shaped. They are found mostly as individuals and not as much in masses, as often found with wheat and rice straw. They vary in length from 40 to 420 micrometre (average 100 micrometre) and in width from 10 to 50 micrometre (average 22 micrometre). Vessels are present in few numbers and their length ranges from 63 to 230 micrometre (average 149 micrometre). Epidermal cells are also few in number with sharp toothed to way margin. They measure from 58 to 100 micrometre (average 73 micrometre) in length and 10 to 20 micrometre (average 16 micrometre) in width. Stomatas are occasionally present (*see* Fig. 13).

B-14 KAHI GRASS

The pulp from kahi grass shows the same diversity of cell type as khar and sabai grass pulp. The fibres are uniform, long and slender with pointed ends as in khar and sabai grass. They are from 700 to 4 700 micrometre in length with average of 1 500 micrometre. Parenchyma cells are numerous and somewhat larger than those of sabai grass. They range from 30 to 380 micrometre (average 143 micrometre) in length and ranging from 10 to 73 micrometre (average 32 micrometre) in width. Vessels vary from very small to big ranging from 52 to 560 micrometre (average 200 micrometre) in length and 30 to 100 micrometre (average 65 micrometre) in width. Epidermal cells somewhat narrow and cylinderical with toothed margins are always present. They vary from 25 to 210 micrometre (average 123 micrometre) in length and from 6 to 20 micrometre (average 11 micrometre) in width. Stomatas are occasionally present, (*see* Fig. 14).

B-15 SABAI GRASS PULP

Pulp made from sabai grass *(Eulaliopsis binata)* is somewhat similar to bamboo and bagasse in general characteristics comprising of the same kinds of cells as shown in Fig. 15. The fibres are remarkably uniform and straight with rather thick walls and sharp, pointed tapering ends. They vary in length from about 600 to 4 000 micrometre with an average of about 1 500 micrometre. In width they are very much narrower than bagasse or bamboo ranging mostly from 5 to 15 micrometre with an average of only 9 micrometre and at once serve to distinguish sabai from the latter.

Compressed areas with transverse markings are found only in a few fibres as compared with the majority in bamboo and bagasse. Parenchyma cells are very abundant, but very much smaller than those of bamboo measuring 30 to 220 micrometre (average 70 micrometre) in length and 10 to 50 micrometre (average 15 micrometre) in width. Vessels fairly long, but very much narrower in width than those of bamboo or bagasse varying from 15 to 45 micrometre with an average of 30 micrometre. Epidermal cells are always present, comparatively more numerous than in bagasse, rectangular in shape with characteristic toothed margins. Spicules of various sizes and shapes, and stomata are also occasionally present.

B-16 JUTE STICK PULP

By jute stick is meant the central woody part and pith of the jute plant (*Corchorus capsularis* and *C. Olitorius),* from which the commercial fibre has been stripped after a process of retting in water. The pulp made from jute stick, like all hardwood pulps shows the same diversity of cell types as in salai described earlier, the various cell elements being completely separated in the chemical pulp. The individual fibres are rather short, measuring 300 to 1 250 micrometre (average 700 micrometre) in length and 15 to 50 micrometre (average 30 micrometre) in width and often show transverse markings due to compression or buckling. The fibre walls as compared with salai are very thin (1.5 to 3 micrometre) and show relatively numerous minute pits with lenticular aperture and indistinct border. The parenchyma cells are comparatively more abundant than in salai or bamboo, 30 to 220 micrometre (average 90 micrometre) in length and 13 to 52 micrometre (average 30 micrometre) in width with very thin walls and numerous simple pits of two types — minute circular ones connecting other parenchyma or fibres and somewhat larger oval ones connecting vessels as shown in Fig. 16. The vessel elements vary from 150 to 800 micrometre (average 400 micrometre) in length and 30 to 140 micrometre (average 80 micrometre) in diameter and have fairly large oval pits 6 to 8 micrometre in diameter. Annular or spiral thickenings of protoxylem elements are also occasionally present.

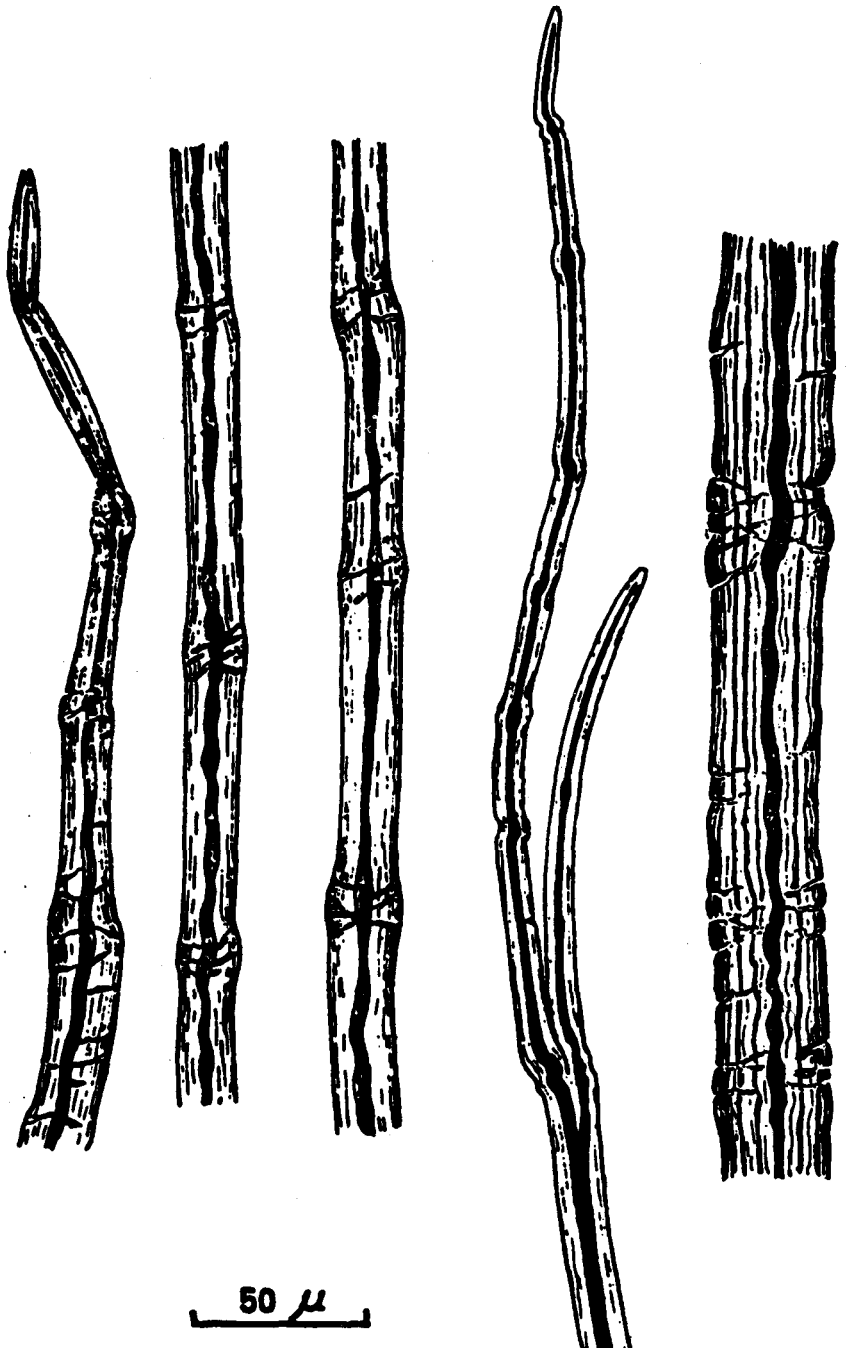


FIG. 5 MORPHOLOGICAL CHARACTERISTICS OF HEMP ROPE CUTTINGS PULP

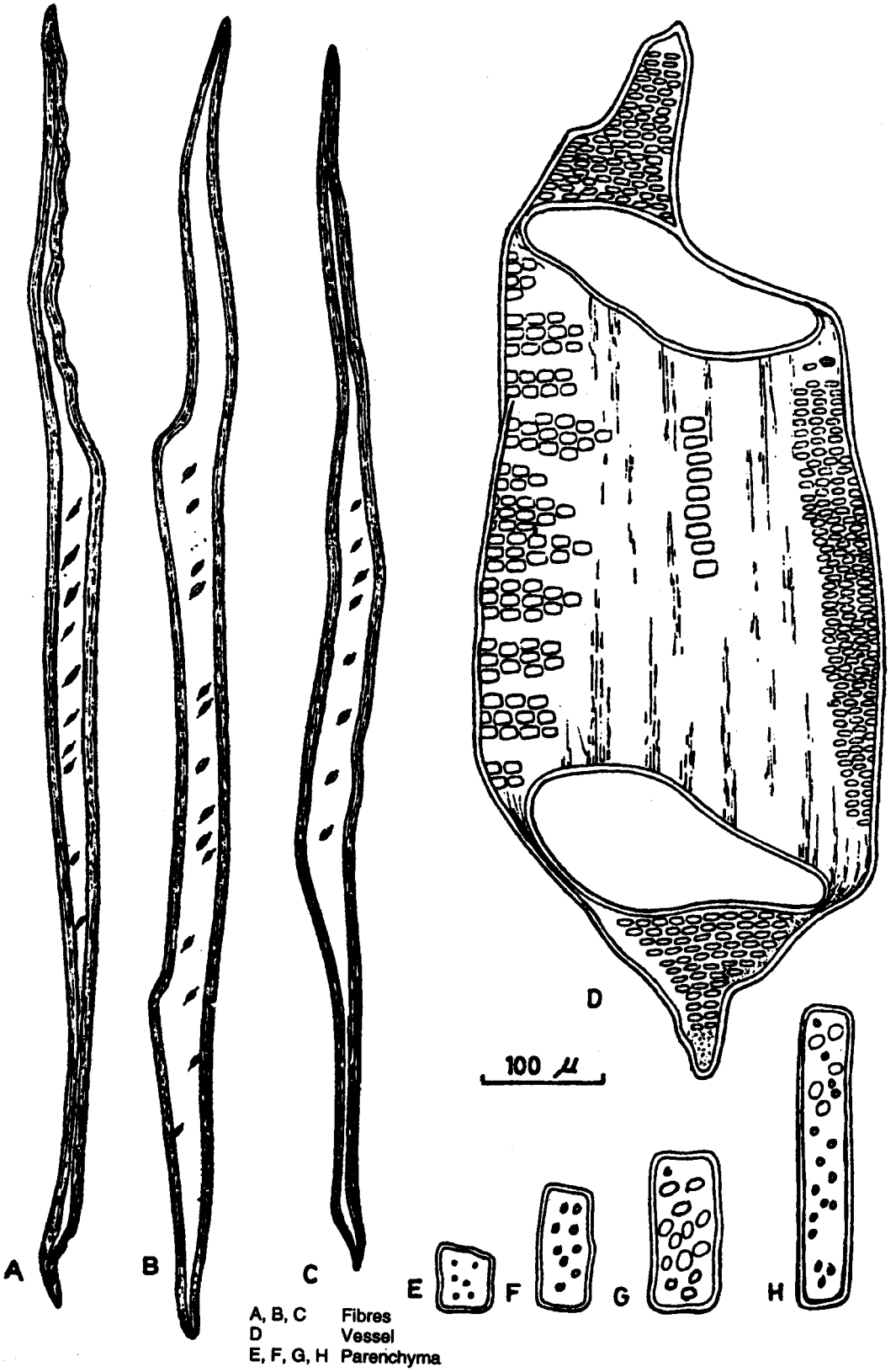
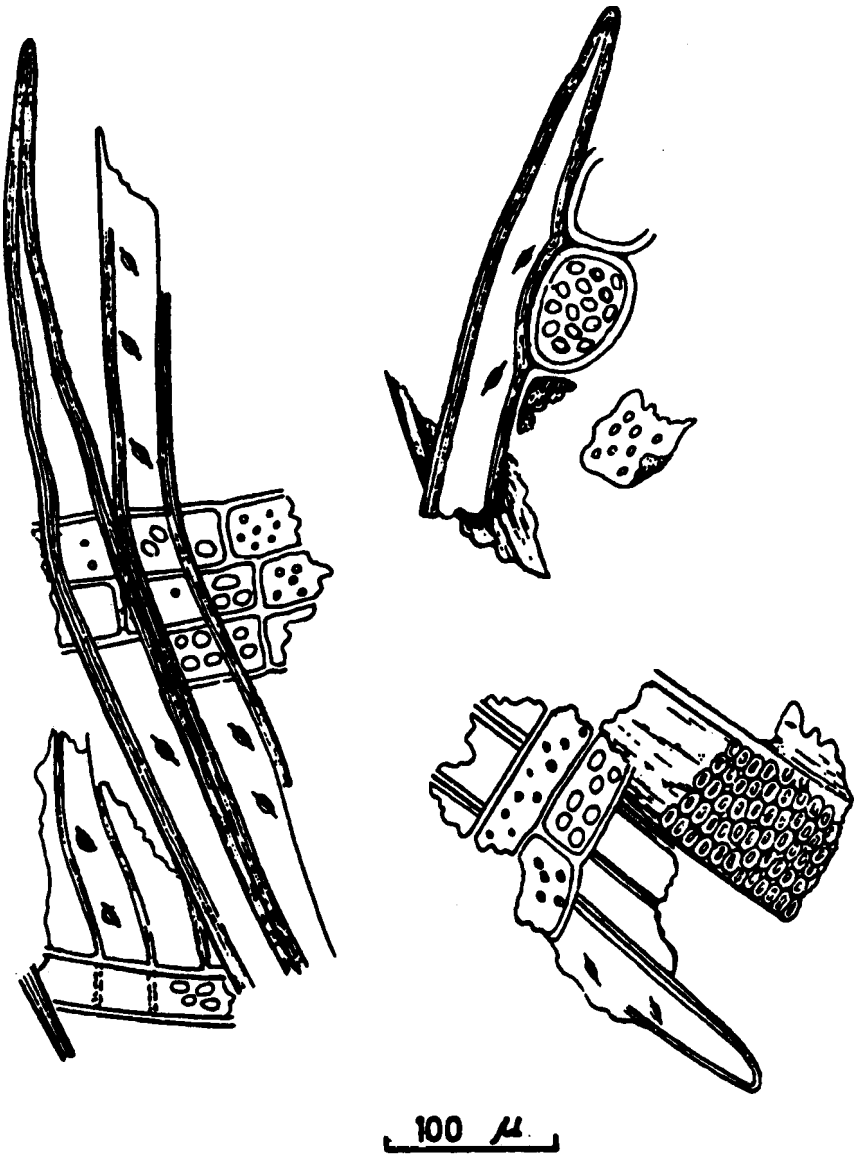


FIG. 6 MORPHOLOGICAL CHARACTERISTICS OF SALAI (CHEMICAL) PULP



Fragments of fibres with torn vessels and parenchyma cells attached.

FIG. 7 MORPHOLOGICAL CHARACTERISTICS OF SALAI (MECHANICAL) PULP

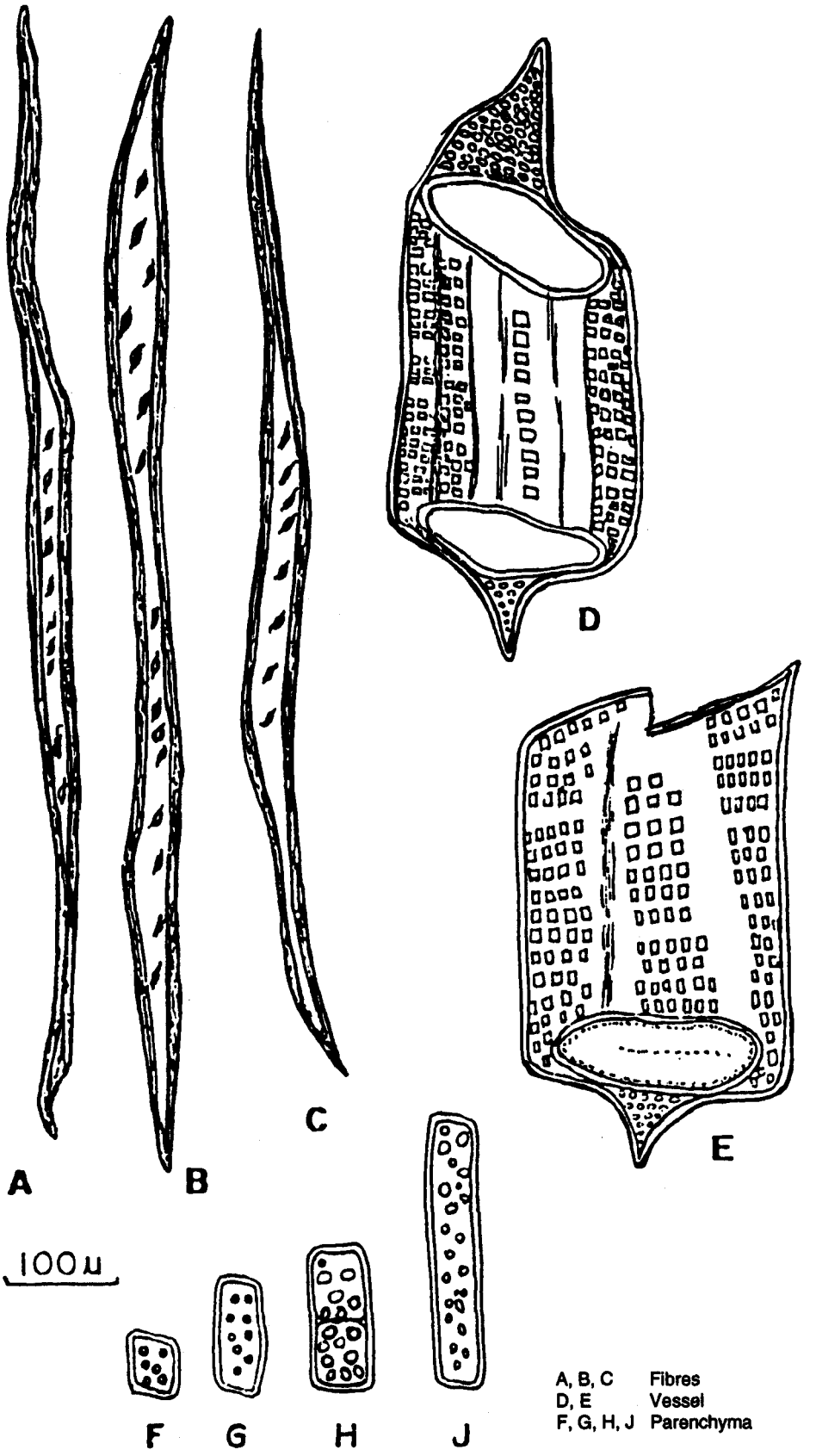


FIG. 8 MORPHOLOGICAL CHARACTERISTICS OF EUCALYPTUS TERETICORNIS PULP

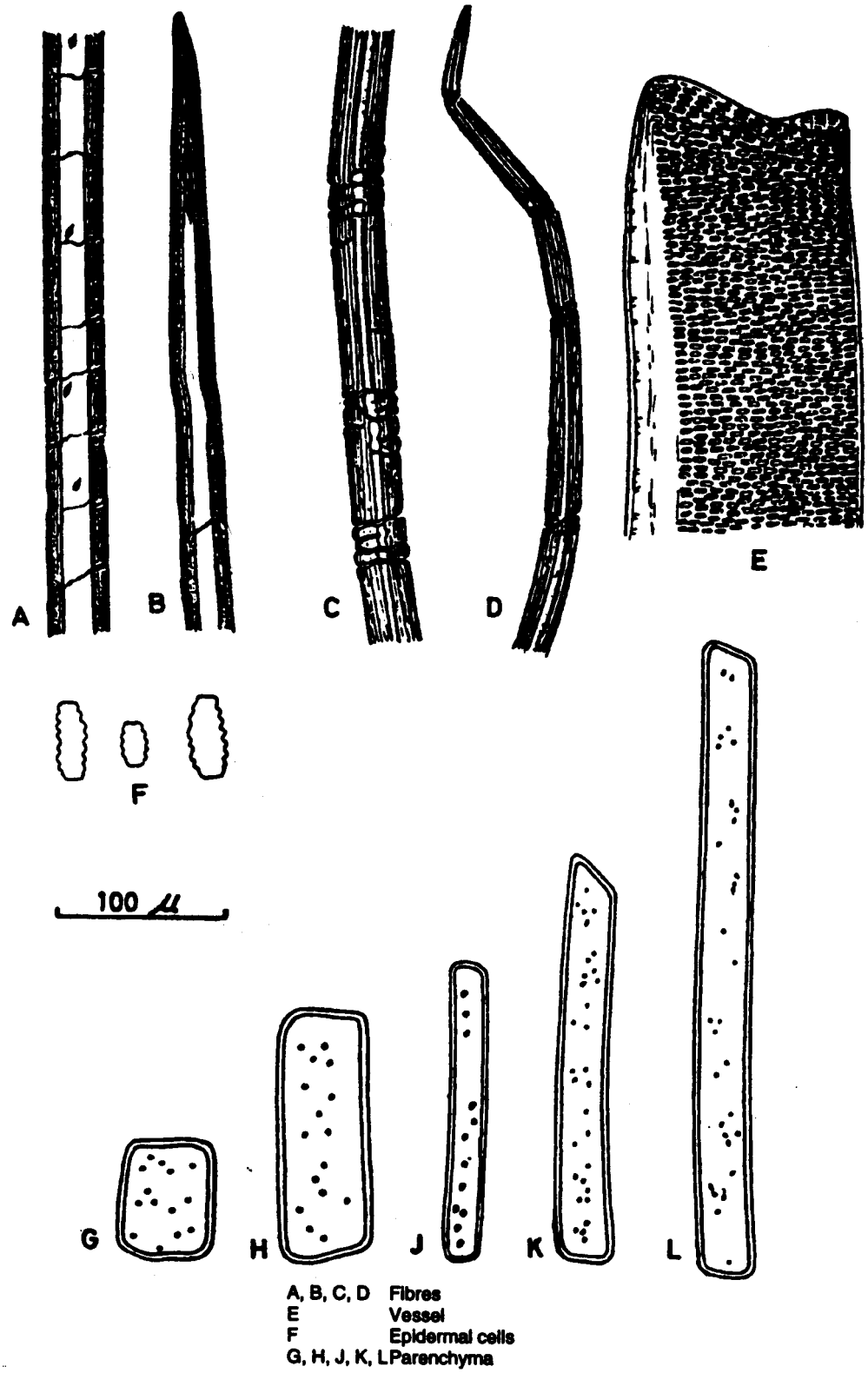


FIG. 9 MORPHOLOGICAL CHARACTERISTICS OF BAMBOO PULP

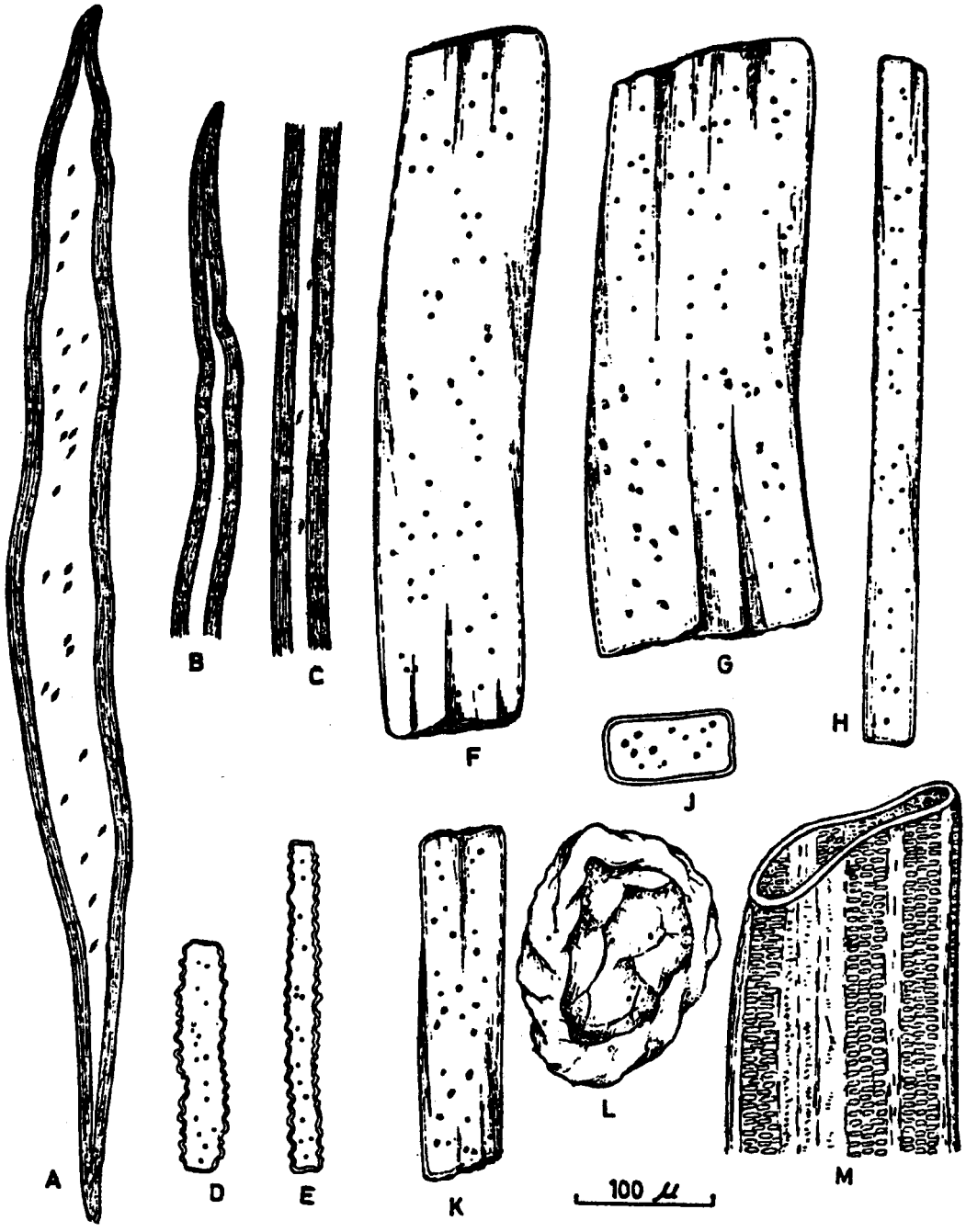


FIG. 10 MORPHOLOGICAL CHARACTERISTICS OF BAGASSE PULP

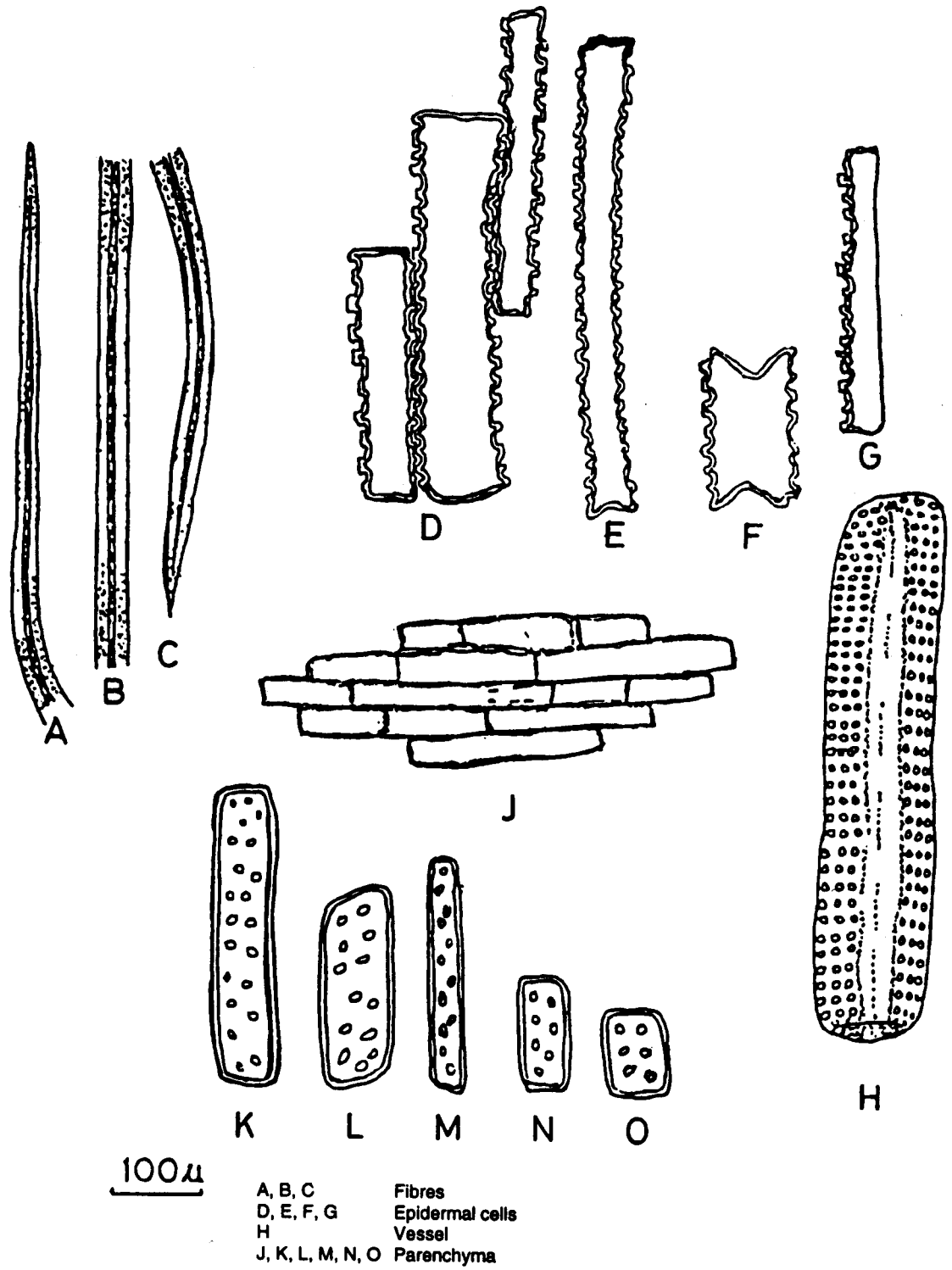


FIG. 11 MORPHOLOGICAL CHARACTERISTICS OF WHEAT STRAW PULP

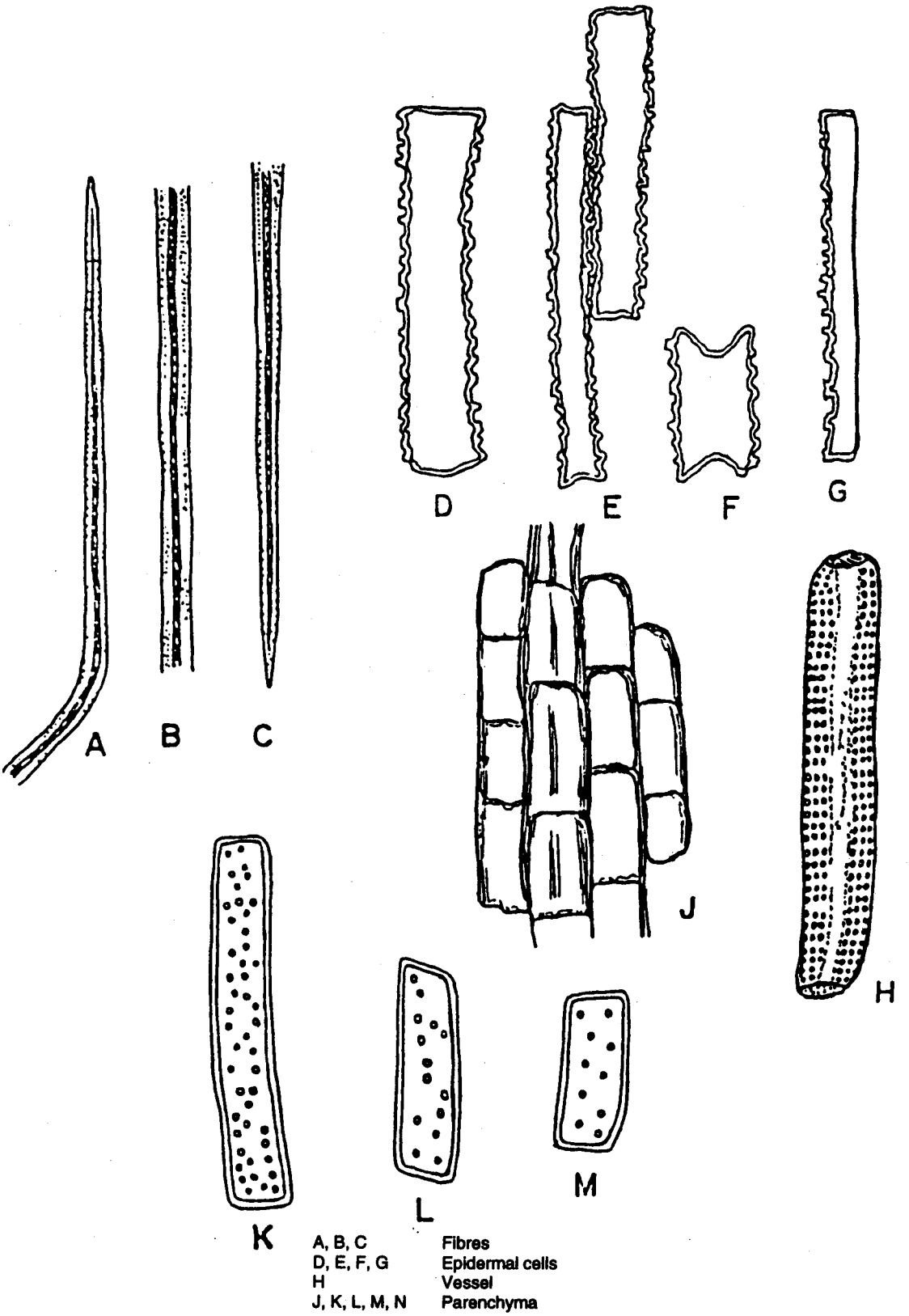


FIG. 12 MORPHOLOGICAL CHARACTERISTICS OF RICE STRAW PULP

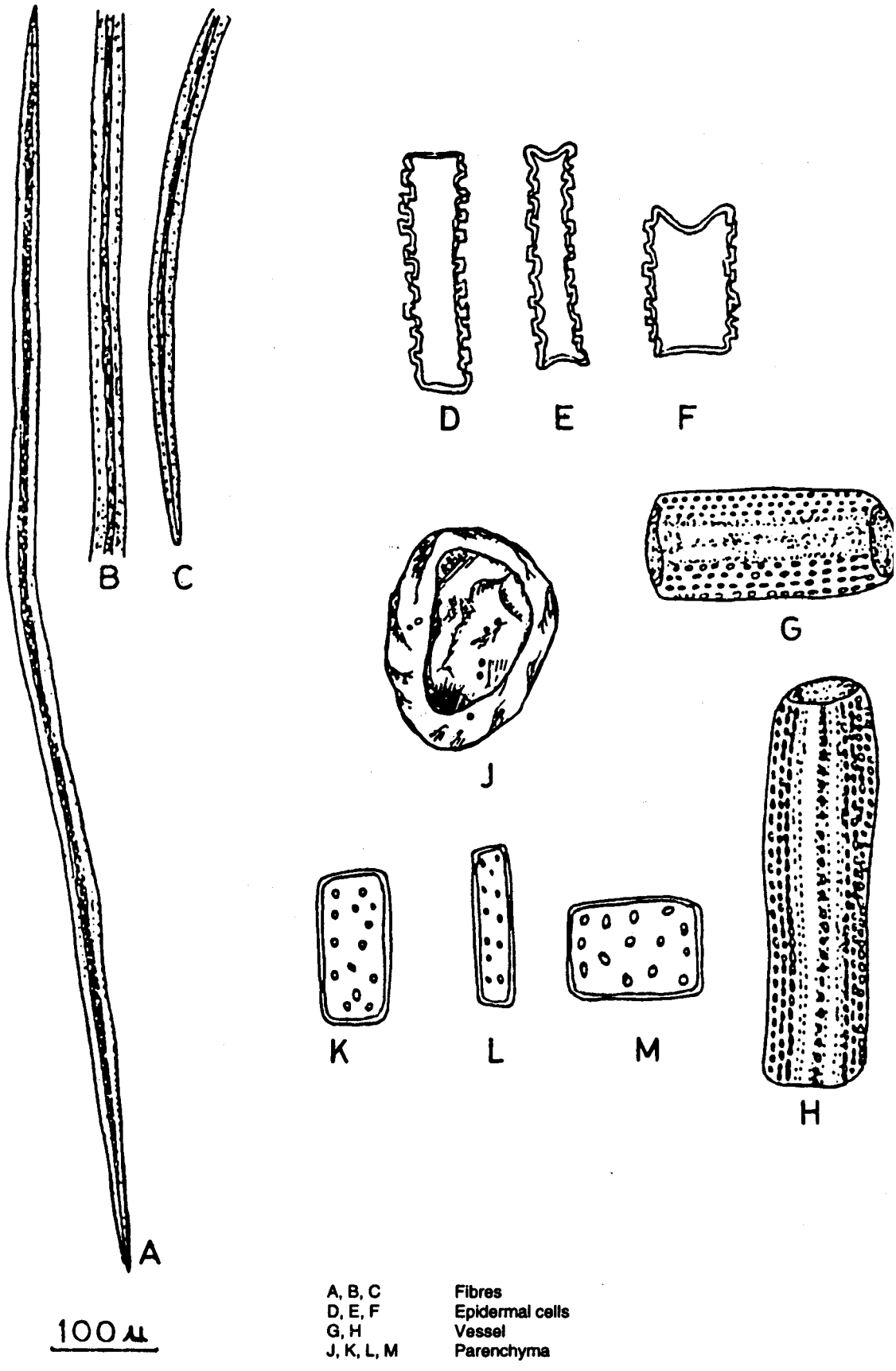


FIG. 13 MORPHOLOGICAL CHARACTERISTICS OF KHAR GRASS PULP

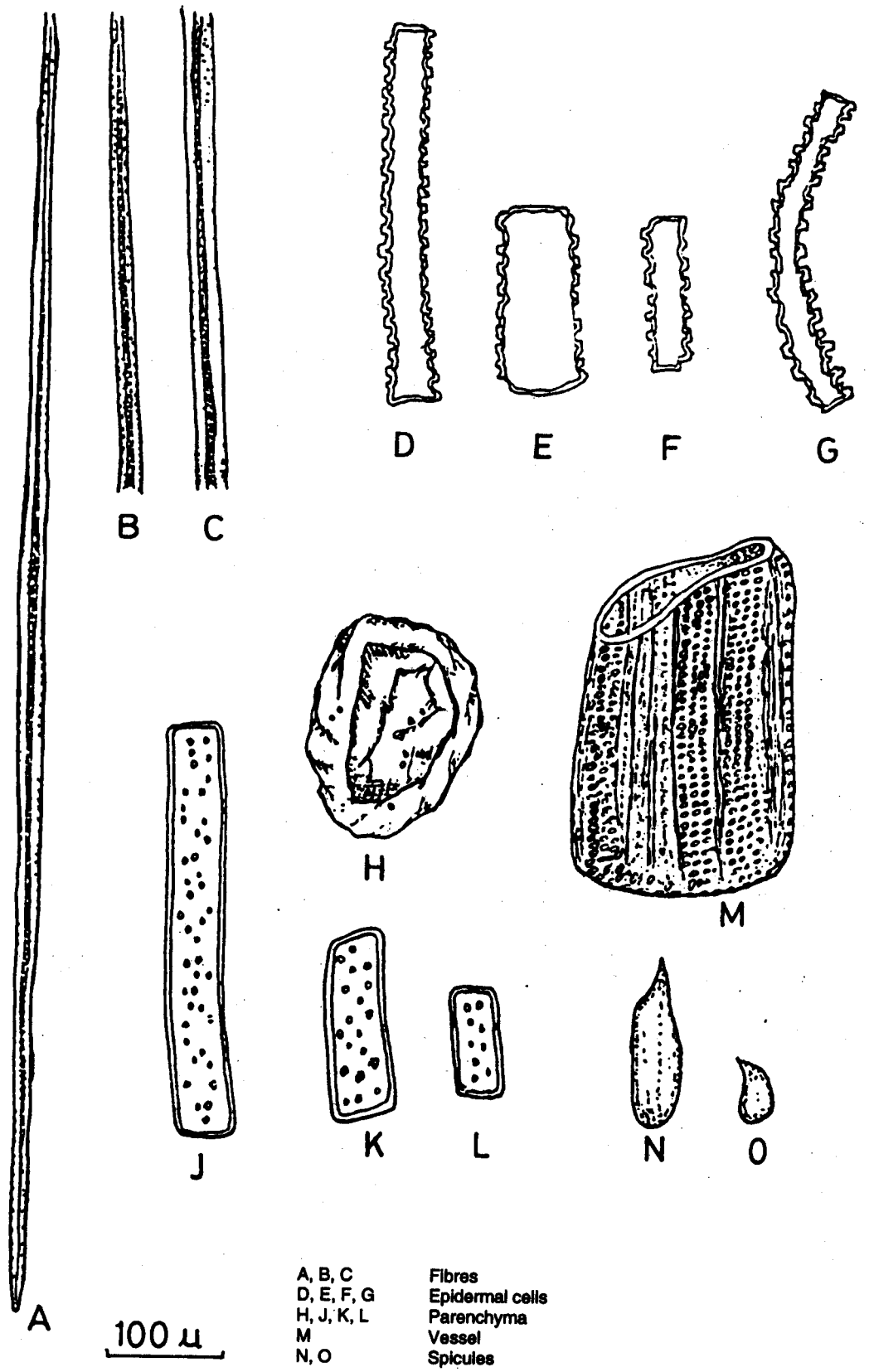


FIG. 14 MORPHOLOGICAL CHARACTERISTICS OF KAHI GRASS PULP

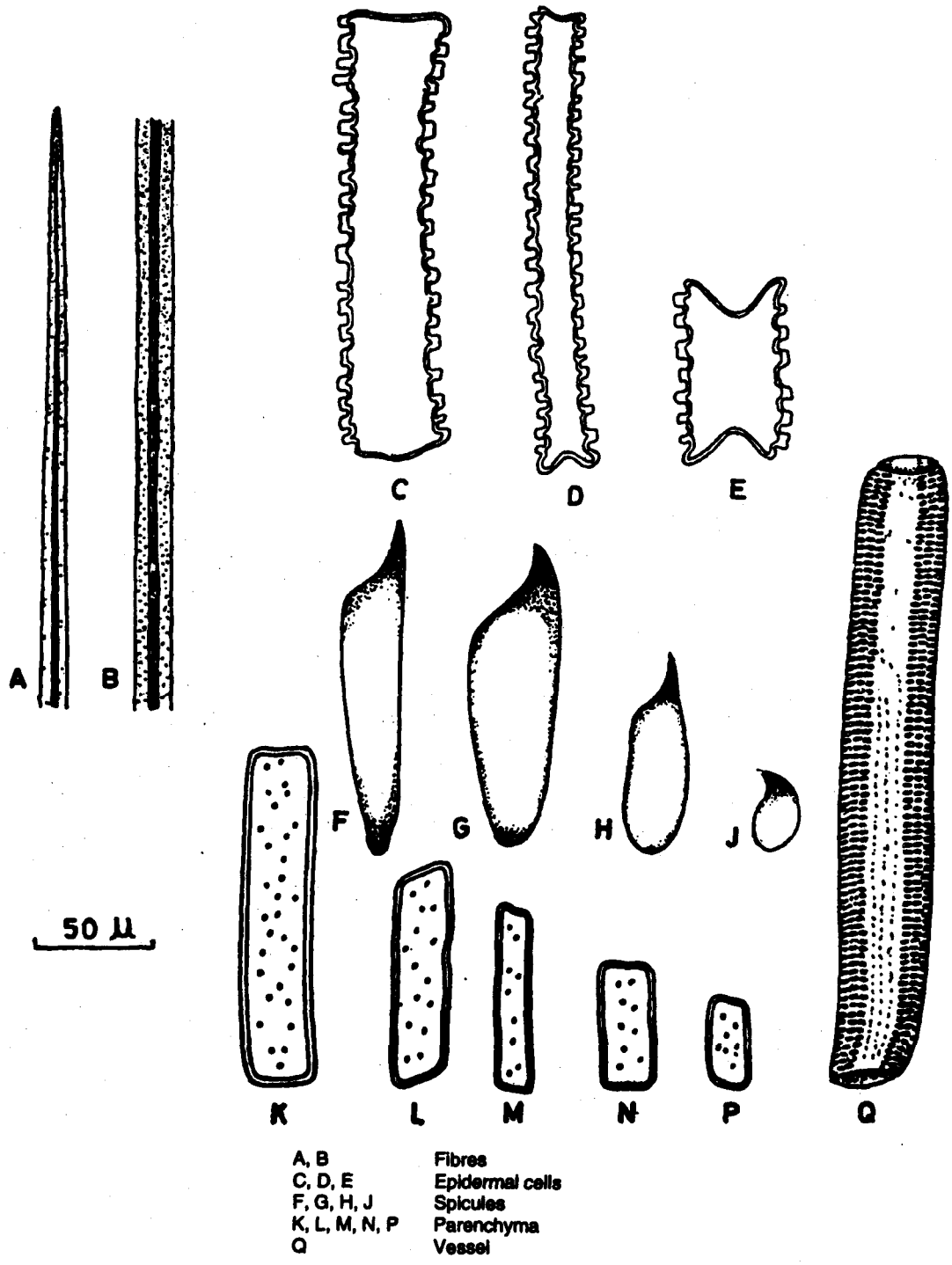


FIG. 15 MORPHOLOGICAL CHARACTERISTICS OF SABAI GRASS PULP

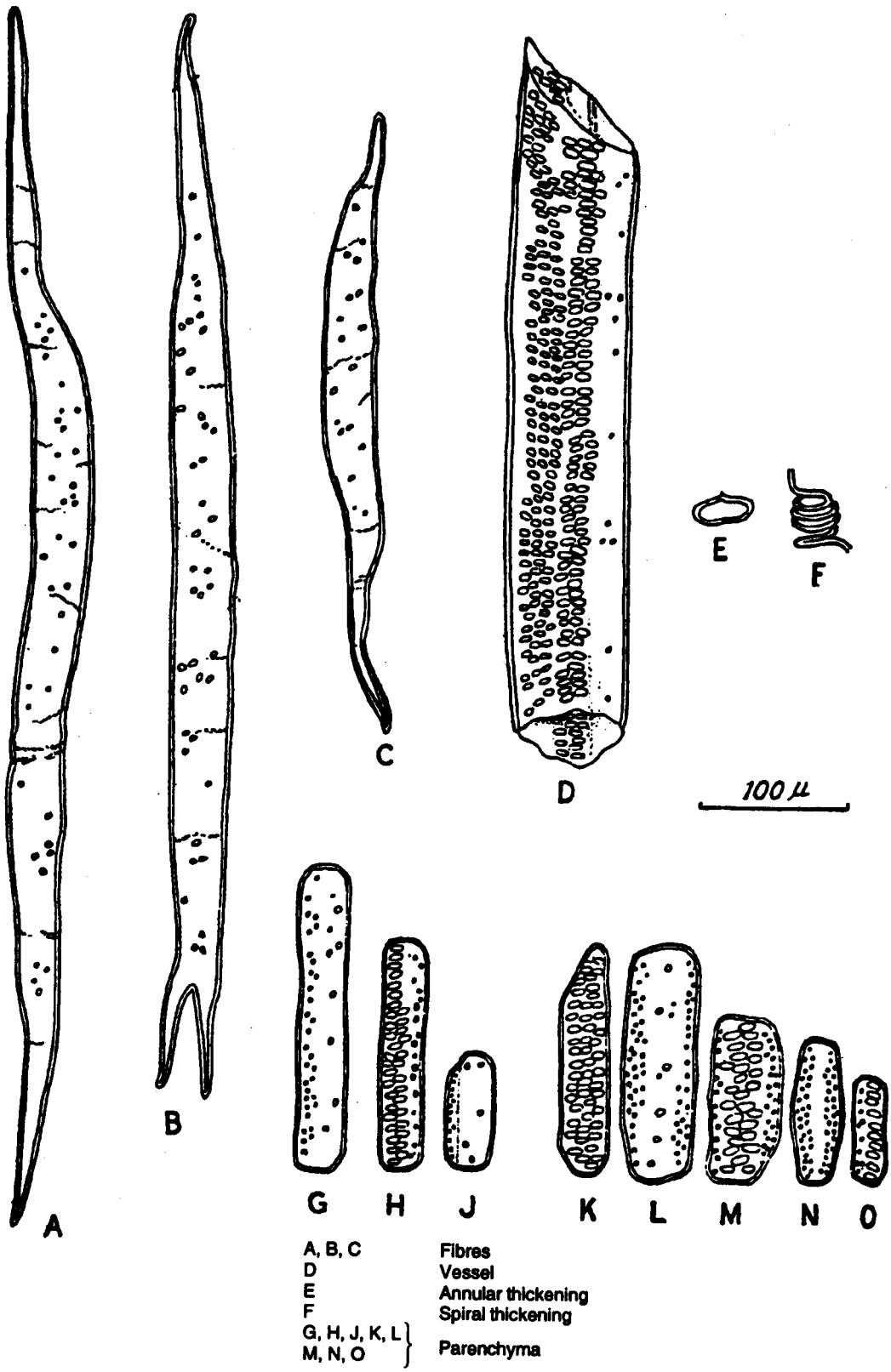


FIG. 16 MORPHOLOGICAL CHARACTERISTICS OF JUTE STICK GRASS PULP

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